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JOURNAL

VOLUME 4 NO. 40 APRIL 1958

VOLUME 4 NUMBER FORTY APRIL 1958 ©

JOURNAL

OF THE INSTITUTION OF ELECTRICAL ENGINEERS

SAVOY PLACE LONDON W.C.2 *Telephone* TEMPLE BAR 7676 *Telegrams* VOLTAMPERE PHONE LONDON

PUBLISHED MONTHLY PRICE SEVEN SHILLINGS ANNUAL SUBSCRIPTION TWO POUNDS

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OF THE INSTITUTION OF ELECTRICAL ENGINEERS
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INTERNATIONAL CONVENTION ON MICROWAVE VALVES

WHEN IN 1946 THE INSTITUTION HELD the first of its post-war conventions, a session was devoted to valves, and prominent amongst the devices discussed were microwave valves—magnetrons, klystrons and crystal mixers. Before the war these were of scientific interest only, but they made striking advances under the stimulus of war-time activity and were by 1945 well established as engineering devices.

The term 'microwave valve' has grown to imply a class of device which is particularly suited for the generation and amplification of energy at the highest radio frequencies, since it makes use of energy transformation mechanisms in which free electrons spend relatively long times (many periods of the r.f. oscillation) in the alternating electric fields with which they couple. Thus they are not subject to the higher-frequency limits due to the finite time of passage of electrons between electrodes, which are characteristic of the more familiar triodes and tetrodes used in our normal r.f. equipment. Their introduction and development have in fact allowed very large increases in frequency, power and amplification factor to be achieved. Because the interaction mechanism of these valves makes them particularly useful for both very high frequencies and very high power, it has been necessary to incorporate the r.f. circuits directly associated with the interaction process within the vacuum envelope, in order to avoid the inevitable changes of dimensions arising from passage of conductors through the envelope. The resonator structure of a multiple-circuit magnetron is perhaps a familiar example of this. As a result, a microwave valve is usually a fairly complex device of metal and glass or ceramic, requiring very accurate fabrication and location of many parts, and subject to the need for withstanding large temperature changes in manufacture in order to achieve a desired vacuum.

The advance of valves of this class during the war had stimulated the growth of the new engineering science of 'microwaves', primarily concerned with the generation of energy of ultra-high frequencies, with its launching into the atmosphere in accurately focused radio beams or its transmission by hollow metallic waveguides; and with its reception and detection. It was natural to expect at the end of the war that activity in this field would diminish and that a period of consolidation would follow in which the fullest exploitation was made of the recent scientific advances. However, as has happened in many other fields, the growth of microwave science has continued at an increasing rate and has stimulated further advances in fundamental and practical aspects of microwave electron devices. Travelling-wave tubes and backward-wave oscillators have now been added to the growing list of established microwave valves. Many other devices are still the subject of extensive research and development, each with its part to play in a rapidly developing and complex technical field.

Numerous publications have appeared on this work, and attention was directed to many of the recent advances in a lecture given before The Institution in 1954.* A number of conferences on the subject have taken place in the United States, and in 1956 an International Congress on Microwave Valves was held in Paris.

Because of the very rapid progress in this field and the great need to maintain and further encourage the exchange of ideas, the Committee of the Radio and Telecommunication Section of The Institution have now made arrangements, with the approval of the Council, to hold an International Convention on Microwave Valves from the 19th to 23rd May 1958. This will correlate present knowledge and discuss new ideas, and particular attention will be paid to work at present in progress or recently completed.

Active interest has been shown in the Convention by workers and organizations in many countries, and in view of the number of papers to be presented, and the desire to give the maximum of time for discussion, the business of the Convention will be conducted generally in two parallel series of sessions. An exhibition, appropriate to the objects of the Convention, will be held at the same time. There will also be a full social programme, and since it is hoped that many delegates, particularly those from oversea, will be accompanied by their ladies, activities of particular appeal to ladies are being arranged.

From the response shown to the initial announcement and subsequently, there is every indication the Convention will indeed be successful in providing an international forum for those active in this important and fascinating field of science and engineering. Anyone interested in attending the Convention can now obtain a registration form by applying to the Secretary of The Institution.

* J. THOMSON: 'Developments in Thermionic Valves since 1939' (Published in 'Thermionic Valves 1904–1954' by The Institution of Electrical Engineers, 1955).

An Electrical Engineering Review

ULTRASONIC MACHINING

621.9 : 534-8

Ultrasonic techniques have made rapid progress since the end of the Second World War and to-day they have many industrial applications: tinning and soldering, treatment of metal melts, surface hardening, acceleration of chemical processes, and flaw detection are some of these. Here Mr. Brockelsby writes about an important and still comparatively new application. Ultrasonic machining is effected by what is essentially a high-speed reciprocating drill, driven from a magnetostrictive transducer, and working with an abrasive. It has useful application to the machining of sintered carbides and ceramics, and it is noteworthy that, although there is room for craftsmanship, unusual skill in operating the machines is not required, and little heating of the workpiece occurs.

The author is with the Mullard Research Laboratories, Salfords, Surrey.

C. F. BROCKELSBY, B.SC., ASSOCIATE MEMBER

REMOVING metal from a workpiece is the commonest operation in a great many manufacturing processes. Conventional methods based on cutting (milling, turning, drilling) fail when the material is harder than the tool. Recourse is then had to grinding: the material is removed by the abrasive action of many very hard particles either embedded in a matrix or carried in a slurry. External grinding is capable of machining a profile with great accuracy and fine finish, provided the detail is not too fine and complicated, but internal grinding is limited to profiles which can be cut with a wheel or reciprocating tool of sufficient diameter to be rigid. Blind holes of complex form present almost insuperable difficulty. These are severe limitations in many fields, such as die making; complicated and costly procedures like that of segmentation have perforce been adopted in the past. A radical departure from conventional methods has been made during the last decade by the introduction of purely electrical machining methods, in which the work is attacked by an electric arc or spark; the latter is superior.

In spark machining, minute fragments are cracked off the work by the thermal shock produced by a spark discharge which takes place under an insulating oil (paraffin) between the work (which must be an electrical conductor) and an electrode having the desired profile. The electrode is fed into the work by a servo which maintains a small clearance. Each spark produces a shallow depression, giving the work a characteristic microscopic ball-peened appearance. At high intensities the rate of cutting is high, but the surface finish and accuracy are relatively poor. To obtain a high accuracy and good surface finish, it is necessary to reduce the intensity and cut slowly. In either case the tool wears away at a rate comparable with (sometimes greater than) the rate of penetration. This method has been highly developed, and several machines of British, American and Swiss manufacture are commercially available.

An alternative means of sinking cavities or piercing holes of non-circular shape is impact grinding, using a tool of the desired profile vibrating longitudinally and cutting the work by means of an abrasive. In the manufacture of extrusion and drawing dies, for example, this method has been highly developed; impact-grinding machines with mechanical vibrators have been designed to operate at frequencies up to several hundred per second, but the rate of cutting is still rather low and the noise problem is severe.

These problems are solved if the frequency is raised by two orders of magnitude, as in an ultrasonic drill, which consists of an electromechanical transducer (usually a magnetostrictor) driving a drill that vibrates longitudinally through a solid stub. The stub is tuned to resonate longitudinally at the working frequency, and provides a solid mechanical support for the whole vibrating structure. The drill operates with an abrasive by chipping the work microscopically.

Each particle removed from the work by an abrasive is small so that very many individual 'cuts' are needed, i.e. the vibration frequency must be high. To produce a fine surface finish—a prerequisite for accuracy of dimensions—a fine abrasive is necessary. The amplitude of vibration of the tool need not greatly exceed the diameter of the abrasive particles, and yet the impulse communicated at each impact of the tool must be large.

The total rate of removal of material from the work will be proportional to the available power of the vibrator. Intense vibration is most easily obtained by resonance, but the mechanical Q-factor should not be too high; if it were, the machine would be critically dependent upon the mechanical damping imposed by the work, and the drive frequency would need very precise adjustment. In practice a mechanical Q-factor of about 100 is acceptable. In a mechanical resonator of effective mass M, vibrating at a frequency $\omega/2\pi$ with an amplitude a when unloaded, the available power is $\omega^3 a^2 M/4Q$. For fairly fine abrasives, a should be of the order of 0·001 in., say 30μ; the effective mass of a practical vibrator of engineering proportions will be about 1 kg. Comparison with conventional machine tools suggests a power requirement of the order of 1 kW.

These values, with $Q = 100$, give $\omega/2\pi = 10$ kc/s, which indicates the order of magnitude of frequency required. A frequency just beyond the range of normal hearing—about 20 kc/s—is actually used.

This combination of relatively high power and high frequency is impracticable by purely mechanical means, but is not difficult to attain by the combination of electronic and electro-acoustic methods. The electronic generator presents no unfamiliar problems; the electromechanical transducer could be based on several principles. Electromagnetic and electrostatic systems are unsuitable because the electromechanical coupling coefficient is too low. Piezo-electric crystals and ferroelectric polycrystalline materials are brittle, and it is difficult to make sufficiently robust joints between them and metals. The transducer of choice is therefore a metallic magnetostrictor, though some new ferrites show promise for future use in place of the metals (nickel or Permendur) now employed.

Design of Ultrasonic Machines

The development of the present technique was begun in the United States in 1944. The first commercially available machine in Great Britain was described by Neppiras in 1953. The current form of this machine is illustrated in Fig. 1. The technique has recently been comprehensively reviewed by Neppiras and Foskett.* The development towards higher powers and greater precision is illustrated in Fig. 2, which shows a current, commerciably available British machine rated at 2 kW.

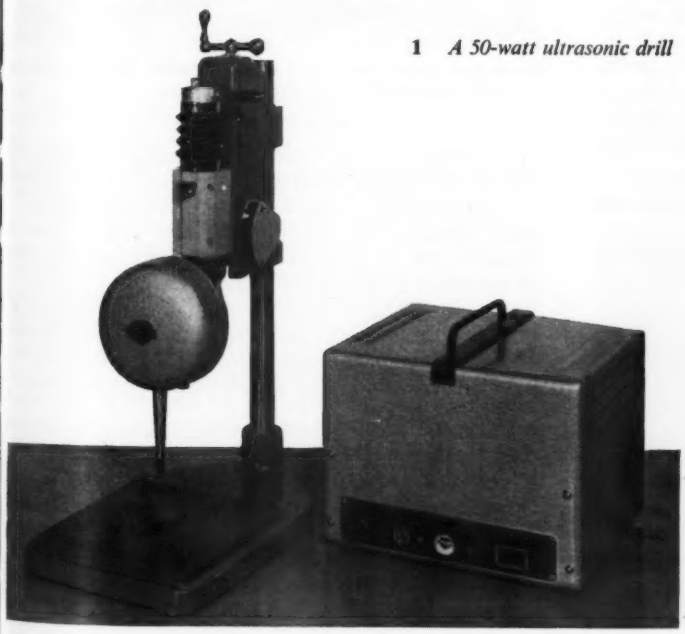
The kind of work which can be produced on such machines is illustrated in Figs. 3, 4 and 5. Fig. 3 shows holes and bas-relief patterns cut in glass; Fig. 4 shows dies and test pieces in tungsten carbide; Fig. 5 shows a die (for blanking a radio-valve anode) in tungsten carbide, with the tools used and the associated steel punch.

It is also possible to drill a hole with a curved axis, and to cut male and female threads. The use of multiple tools is also valuable; for example, an 'egg-box' tool (which can itself be made in tungsten carbide on the same machine) will cut a slice of material into 100 or more dice in one operation—a process used on germanium in the mass production of transistors.

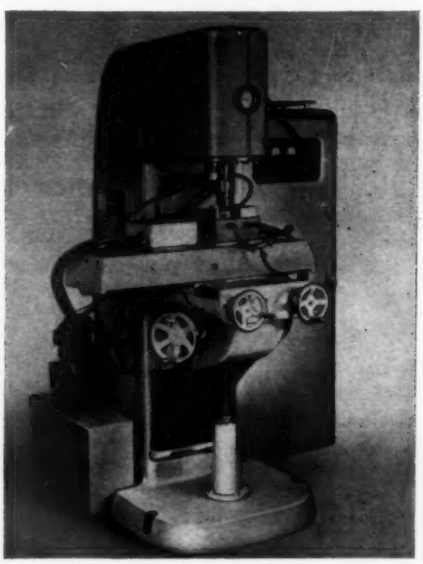
The simplest drilling head consists of a magnetostrictive bar to which the tool is directly attached (Fig. 6). The change of length in a magnetostrictive material, produced by the longitudinal magnetic flux in it, is independent of the direction of the flux. Simple sinusoidal flux excitation therefore produces vibration at twice the frequency of the excitation, and the vibration amplitude is small unless the flux density approaches saturation, when the electrical losses are excessive. The sinusoidal drive flux is therefore superimposed upon a steady polarizing flux, for which the optimum value is around two-thirds of the saturation value.

The length of the bar is fixed by the working frequency of about 20 kc/s, since the bar is operated in its fundamental resonant mode, at which its length is one half-wavelength of sound in the material. The velocity of sound in metals is about 5 km/sec, so that the length of the bar is about 12·5 cm. To obtain mechanical rigidity and to accept a useful power input the bar needs a cross-section of about 5 cm². The demagnetizing factor for such a bar is large, and so an external flux path is provided by yokes of silicon iron. In order to reduce eddy-current loss, the bar is laminated longitudinally; it is

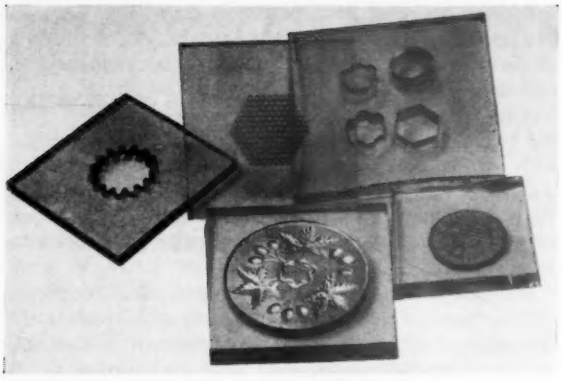
* Neppiras, E. A., and Foskett, R. D.: 'Ultrasonic Machining', *Philips Technical Review*, 1956–57, **18**, pp. 325 and 368.



1 *A 50-watt ultrasonic drill*



2 *A 2 kW ultrasonic drill*



3 *Specimens cut in glass by ultrasonic machining*

consolidated with an epoxy resin. Cooling is by convection only, which limits the input power to about 60 watts.

A steel shoe is brazed to one end of the bar, with a threaded hole for attaching tools, and the unit is mounted in a clamp at the centre of the bar, where there is a node of vibration. Such a head mounted on a ball slide, with an adjustable constant-rate spring to support the head and regulate the static pressure on the work, forms the small machine illustrated in Fig. 1.

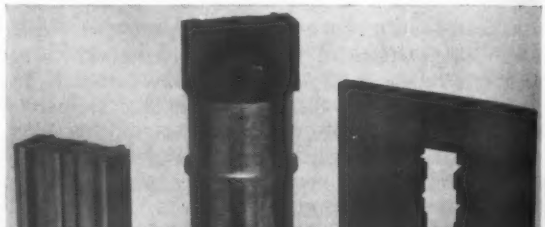
The static magnetostriction in all materials is small, the saturation strain being about 30×10^{-6} for nickel. The vibration amplitude away from resonance at working flux levels, which are an order of magnitude below saturation, is therefore of the order of $0{\cdot}1\mu$. The amplitude at resonance is Q times greater, of the order of 10μ, but is still rather small for effective drilling. A further increase is obtained by the use of a tuned velocity transformer, consisting of a solid, tapered metal horn; the operation is governed by the acoustic horn equation. Neppiras has given the theory of an exponential taper, which transforms the amplitude in the inverse ratio of its end diameters. The large end, attached to the vibrator, preferably has an area somewhat larger than that of the vibrator; the small end should have the same area as the tool attached to it. Horns of different ratio are thus needed for different tools; in practice three sizes often suffice.

An alternative form of resonant velocity transformer consists of two cylindrical sections of different diameter, each a quarter-wavelength long. The amplitude ratio is the square of the diameter ratio (greater than in the exponential horn), but the maximum stress, for a given end amplitude, is greater than in an exponential taper.

The small machine described above (Fig. 1) is widely used in industry for drilling glass and ceramics and for making small dies in tungsten carbide, e.g. for wire drawing. It is, however, limited in capacity by the low power rating (60 watts) and small dimensions of the vibrator; it is also limited in precision by the vibrator mount, which is a small clamp on the soft nickel core.

For larger work of high precision, such as the making of gauges and press tools, a larger machine is required (Fig. 2). This uses a water-cooled transducer rated at 2 kW input; the flux return path is integrated with the vibrator by using a 'window' construction. The transducer is supported on a velocity transformer mounted by a solid flange at its nodal plane. The drilling head is mounted on accurate slides in the head of a machine resembling a conventional milling machine.

4 *Specimens cut in tungsten carbide by ultrasonic machining*

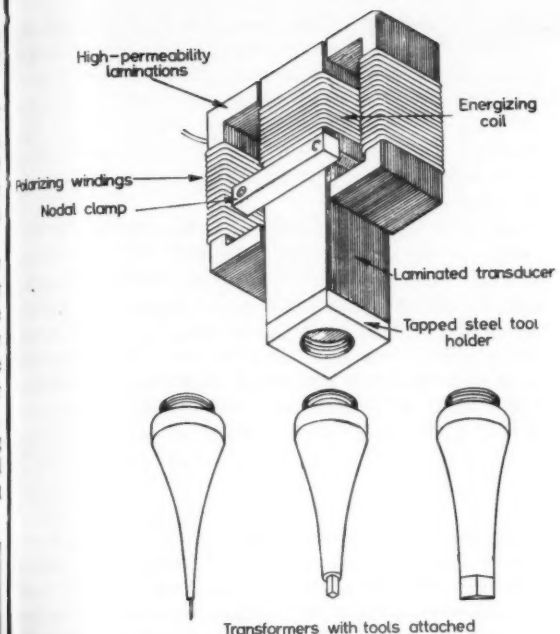


5 *A tungsten-carbide die for valve anode blanks, with the tools used and a blank produced by it*

Similar machines have recently appeared in France, Germany, Switzerland and the United States. Russian and Japanese publications refer to the principles but have not yet announced an engineered machine tool.

Performance

The cutting speed depends upon a number of factors; the machine settings, the tool, the abrasive and the work material. Energy considerations indicate that the cutting speed should be proportional to the square of both the amplitude and the frequency of vibration of the tool. At frequencies up to a few hundred cycles per second, a



6 A 50-watt drill transducer with velocity transformers

square-law variation with frequency is found in practice, but at more than a few kilocycles per second the rate of increase falls. The range 20–25 kc/s gives satisfactory performance with vibrators of acceptable size while avoiding the severe noise problem which occurs at lower frequencies. The square-law variation with amplitude, corresponding to a linear variation with power input, is fairly accurately obeyed.

The static pressure on the tool affects the cutting rate. With zero pressure there would be no effective contact with the work; at a pressure great enough to keep the tool in contact with the work throughout the vibration cycle there would again be no cutting action. Thus there exists an optimum static thrust, the value of which depends upon the tool area and the drive power. The material of the tool has no significant effect.

The shape of the tool has some effect on the cutting rate, owing largely to the difficulty of securing an adequate supply of fresh abrasive under large flat areas. For this reason the rate is increased if there is a small pilot hole communicating with the abrasive supply. There is also a marked advantage in using a hollow tool, provided that the wall thickness is not unduly reduced. Tools of complicated shape involving long thin webs present a large lateral area to the work, and this tends to reduce the tool amplitude by viscous damping. Such tools are also sometimes subject to flexural modes of vibration, which result in uneven cutting and tool wear.

The abrasive slurry should be as concentrated as possible while still retaining sufficient fluidity for free flow, i.e. about 30% by volume. Water is the best liquid. The slurry is violently agitated by the vibration, and this helps to promote the supply of fresh abrasive and the removal of swarf under the tool.

The cutting rate increases with the grain size of the abrasive. It also depends upon the relative hardness of the abrasive and the work material: glass can be cut efficiently with moderately hard abrasives such as alumina and silicon carbide; alumina and tungsten carbide with boron carbide; but diamond only with diamond.

The property of the work material which governs the rate of cutting is its fragility, i.e. the ease with which small pieces (of the order of 0·001 in.) can be chipped off by impact. An indication of the relative rates of penetration is given in the following table, which applies at room temperature. Cooling greatly increases the fragility of most materials, but this technique has not been explored.

Approximate relative cutting rate	Material
100	Soda glass. Barium titanate ceramic.
70	Flint stone. Hard glass. Quartz crystal. Soft porcelain.
50	Hard porcelain. Spinel.
30	Ferroxcube. Germanium crystal.
20	Fused alumina. Ruby. Sapphire.
10	—
7	Brass. Beryllium.
5	Tungsten. Titanium.
4	Tungsten carbide. Stellite.
2	Hard steels.

The abrasive acts on the tool as well as the work. If both are of the same material, the tool wears at about the same rate as the work is cut. The tool therefore needs properties opposite to those desirable in the work, and it should be tough and ductile. Mild steel is good for work on glass and ceramics; the longitudinal tool wear is of the order of 1% of the depth of penetration. For working tungsten carbide, an annealed hard tool steel, such as Poldi Boz,* is best, giving longitudinal wear of 25–40%. It is an advantage to square off the end of the tool as soon as it becomes rounded by wear.

The accuracy of the work is determined by the grain size of the abrasive and the shape of the tool. There must always be clearance between the tool and the work for the abrasive, which reaches the cutting end of the tool by passing between its shank and the work. The tool wears into a tapered form as cutting proceeds. For these reasons, a pierced hole is always tapered; e.g. a hole through $\frac{3}{8}$ in. tungsten carbide, cut with an initially parallel tool and 200-mesh boron carbide abrasive, tapers by 0·001–0·002 in. The effect is reproducible, and the dimensions of a hole cut with even a relatively coarse abrasive such as 200 mesh can be predicted to $\pm$0·002 in.; the tool used would be 0·005 in. radially undersize.

For greater accuracy, this roughing cut is followed by one using a finer abrasive, say 400 mesh. This tool would be 0·001 in. undersize and would be long enough to pass

* Heavy-duty high-tensile steel of approximate composition: carbon 0·4, nickel 2·0, chromium 1·0, molybdenum 0·15, iron 96·45.

right through the work, giving a lapping action which reduces the taper to about 0·0005 in. and improves the accuracy to better than ±0·001 in. If a still finer control is required, a third cut with a full-size tool and 800-mesh abrasive will give a taper of about 0·0003 in. and a clearance of the same order between the work and a new full-size tool. Finally, a mirror finish can be imparted by lapping (still on the same machine) with a full-size tool and a polishing grade of abrasive such as 2000 mesh.

It will be seen that, as in any other high-precision field, there is room for craftsmanship. An operator capable of fine work on conventional machines rapidly gets the 'feel' of this new technique and is able to adapt his previous skills to it.

The above discussion of the accuracy assumes, of course, that the machine movements are capable of the requisite precision. This involves no new techniques, but ultrasonic machine tools must differ from conventional ones in some respects. Since the pressure on the work is important, the axial movement of the tool must be very free. A satisfactory movement is given by mounting the drilling head on precision ball slides, which must be more thoroughly free from particles of dust and metal than is necessary for conventional applications; ultrasonic cleaning has been successfully used. It is also necessary to protect these slides and the other machine movements from the abrasive slurry: the vibrating tool can atomize the slurry into the air, though this does not normally occur during drilling. The other points requiring special attention arise from the powerful vibration and the fact that this is propagated as a wave motion with a wavelength of a few inches. Tool attachment by means of chucks or collets is not possible except for very light work. Standard binding tapers cease to bind under ultrasonic vibration, or, if driven in very hard, seize up—an observation which is made use of in ultrasonic welding. Special tapers are used for relatively light work such as sizing drawing dies in the millimeter range. In general, the only satisfactory union is a pair of surfaces flat to about 0·001 in., located very near an antinode of vibration, pressed together by a screw or clamp and provided with a grease film and/or a soft washer, e.g. of quenched copper, to give an acoustic joint. Such systems can be built to give sufficient accuracy of both lateral and angular location. One important aspect of the design problem is the limitation imposed by fatigue in the materials. It is important to avoid 'stress raisers'. The stress distribution along the vibrating structure resembles the voltage distribution of a standing wave on a short-circuited transmission line, while the amplitude distribution resembles the standing wave of current. Joints can be made only near stress nodes, i.e. the detachable tool must either be short (up to about 2 in.) or an integral number of half-wavelengths long.

Applications

The range of applications over which ultrasonic machining is in direct competition with conventional techniques is narrow. One example is making simple dies such as those for drawing round wires; this process in ultrasonic machining in tungsten carbide gives a saving of about 50% in time, compared with conventional methods, in one typical factory where it has been adopted. This installation uses a special machine of about 100 watt rating, representing a capital investment of about £500.

The new technique is of most importance for work which is very difficult or impossible by conventional methods, such as threading sintered carbides or cutting complex dies like those in Fig. 5, which conventionally can only be made by segmentation. This is extremely costly and gives a weak die. For such work ultrasonic machining must be compared with spark machining. The capital investment involved is about the same, around £2000 to £3000; the total machine time is also comparable, a few hours for a die like those in Fig. 5; a similar degree of attention from the operator is also required. Most spark machines cannot give the surface finish which is obtained by ultrasonic machining, and there is some suggestion that the thermal shock mechanism of spark erosion leaves the work stressed. Spark erosion is not applicable to insulating materials, such as sintered alumina, which are coming into increasing use. On the other hand, spark erosion removes material much faster than is possible by ultrasonic machining in roughing operations: it has therefore been suggested that the two techniques should be combined, using spark erosion for roughing and ultrasonics for finishing. A composite machine of this kind would present no great engineering problems and would cover the complete range of materials from steels (on which ultrasonic machining is slow because they are not sufficiently fragile) through the sintered carbides (where both techniques would be used) to insulating materials.

Summary

Ultrasonic machining has been developed during the last decade and is a valuable extension of earlier impact-grinding techniques. The high frequency leads to vibrators of convenient size which can yet handle high powers. The technique is most efficient for hard, chippable materials which are most difficult to work by conventional methods. Its cost and performance in high-precision work are comparable with those of spark machining, but the ultrasonic method is equally applicable to electrical insulators. Small and inexpensive machines, which are still practical tools, are in common use in Great Britain, and large high-precision machines are now available throughout the Western world; Russia and Japan are not far behind.

Acknowledgments

Acknowledgment is due to the Director of the Mullard Research Laboratories and to Mullard Ltd. for permission to publish this article and to Kerry's (Ultrasonics) Ltd. for permission to reproduce the photograph in Fig. 2.

Convention on Radio Aids to Aeronautical and Marine Navigation

Synopses of the papers read at the Convention on Radio Aids to Aeronautical and Marine Navigation, which was held on the 27th and 28th March in the Institution building, are given below. The complete proceedings of the Symposium, comprising the papers and discussions, will be published as a Supplement to Part B of the Proceedings of The Institution, and an announcement about this will be made later. Individual reprints of papers will not be available.

Thursday, 27th March

Session 1. OPENING SESSION

A Review of Radio Aids to Aeronautical and Marine Navigation

Paper No. 2582: *Part B*

CARADOC WILLIAMS, B.SC.

The paper is an introduction to the Convention.

The parts of the r.f. spectrum which are in use for navigational purposes extend from about 10 kc/s to 40 Gc/s. The basic factors which apply to all radio-navigational technique are the wave-path measurement of time interval, the wave propagation velocity, base-line distance and aerial aperture. For short-distance navigation the predominating source of error is usually in the measurement of time interval, but at greater distances it is due to an inexact knowledge of the wave propagation velocity.

The navigational requirements of ships and aircraft are similar, but the means of meeting these requirements differ, because ship navigation involves movement in two dimensions and aircraft in three dimensions. For example, this has caused the design of shipborne and airfield radar aerials to differ appreciably. Developments of radar in frequency bands above 30 Gc/s is continuing in order to obtain systems with greater resolving power, but at these frequencies the high energy absorption during heavy rain is a handicap to their use.

Self-contained aids to navigation such as dead reckoning, Doppler and inertial navigation involve integration processes, the errors being dependent upon the quality of the information used and the integration time. They have a wide field of application over the undeveloped parts of the world, but in areas of high traffic density, their ability to give adequate protection against collision is obscure. In consequence, navigational techniques which define a common co-ordinate system to all users within their coverage are preferred. The V.H.F. Omni-Range, Tacan and Dectra systems are mentioned as examples of these techniques.

The author discusses precision navigation applied to the landing of aircraft and the berthing of ships. The suggestion is made that pilot vessels should be fitted with high-precision radar for berthing operations, and v.h.f. television links should be used to assist the pilot of the vessel being berthed.

Session 2. MEDIUM AND LONG RANGE AIDS

Survey of Long-Range Radio Navigation Aids

Paper No. 2571: *Part B*

J. C. FARMER, B.SC.

The paper indicates the progress in development and usage of long-range radio aids to navigation in the last decade, and is almost exclusively concerned with air navigation. Some indication is given of the changing operational requirements, and of the extent to which the choice of future aids is likely to be affected by them and by economic and international considerations.

The main features and anticipated performance of new aids are summarized, and particular reference is made to aids which are in an advanced state of development but have not been the subject of papers presented to The Institution.

The conclusions reached are that for at least 10 years considerable use will be made of self-contained aids, on Doppler or inertia principles, particularly for air navigation. Ground-based systems will still need to be used to complement the self-contained aids, and for marine purposes where justified. Economic considerations, however, are likely to limit the deployment of the more expensive ground-based systems to those regions or routes where particular problems of congestion or navigation arise, and these considerations will doubtless govern the final choice of such an aid.

The Decca Navigator System for Ship and Aircraft Use

Paper No. 2567: *Part B*

C. POWELL

The paper discusses the present use of the Decca Navigator radio position-fixing system as a marine and aircraft navigational aid. The permanent navigational service currently comprises 12 chains and some 4 000 ship and aircraft installations; in addition, mobile chains are used for surveying and exploration. The absence of modulation permits close spacing of the chain frequencies. The receivers contain a reference system giving a common phase datum for all users.

The system is a c.w. hyperbolic one in which, in ships, the fixing co-ordinates are normally indicated as phase-meter (Decometer) readings. Aircraft normally use an automatic plotter driven from the receiver by an impulse-motor servo system. There are several types of airborne receiver, and for certain airborne applications a servo system imparting an inertial characteristic to the displayed data is employed. The system can be combined with a navigational aid of the Doppler type to form the Dian system, and the Dectra long-range aid, also part of Dian, has common ground and airborne equipment with the parent Decca Navigator system. A recent development includes a zone-identification facility and employs a new form of transmission that substantially increases the range at which lane identification is effective at night.

Low-Power C.W. Doppler Navigation Equipment

Paper No. 2566: *Part B*

J. E. CLEGG, M.SC.TECH., *and* J. W. CROMPTON, B.E.

A low-power c.w. Doppler navigation aid is described which has been designed for use in maritime reconnaissance aircraft. Low-voltage klystrons combined with high-gain fixed aerials provide adequate system gain for operating over all surfaces except the calmest water. Display is in the form of drum counters showing distance flown along heading and distance

drifted at right-angles to heading, port or starboard. Accuracy of measuring these distances is within ±1% of the total distance flown.

Doppler Navigation *Paper No.* 2568: *Part B*

J. E. CLEGG, M.SC., *and* T. G. THORNE, B.SC.

This paper describes a self-contained radio navigation aid for aircraft which works by virtue of the Doppler principle. Ground speed and drift angle are determined by measuring the Doppler shifts that occur when signals transmitted from a moving aircraft are reflected back from the ground along two or more beams. Ground speed with an error of less than 0·2% and drift angle with an error of less than 0·2° can be obtained with suitable equipment.

Drift angle is combined with heading from the aircraft compass to give direction of travel with respect to North, and this information together with ground speed is fed to a unit which computes the aircraft's present position. In general it is found that the accuracy of the indicated position is limited by the accuracy of the aircraft compass.

The authors describe the various units of the system, including an aerial which simplifies the problem of obtaining adequate accuracy. The errors are analysed and experimental results are given for those that occur over sea.

An account is given of the basic experimental equipment built and tested at the Royal Radar Establishment.

An Airborne Doppler Navigation Equipment *Paper No.* 2572: *Part B*

G. E. BECK, B.SC., *and* T. G. THORNE, B.SC.

The paper gives an account of Airborne Radio Installation 5851, the first Doppler navigation equipment to be used by the Royal Air Force. The way in which the requirements of the specification have been met is described, and an account is given of the special features which have been incorporated in the design. The authors discuss performance and reliability under Service conditions.

The Combination of Inertial Navigation and Radio Aids *Paper No.* 2570: *Part B*

A. STRATTON, M.SC.

By measuring forces and moments that constrain a body of known inertial characteristics to move with a vehicle it is possible to determine acceleration in a set of specified axes and hence change in velocity and position. The principles of this method of navigation, known as *inertial navigation*, are outlined, and it is shown that the many possibilities of a practical realization can all be expressed in terms of a single block schematic of a computer, which corrects for the expected variations in the specific force of gravity as a function of position and time.

The magnitude of the problem of designing suitable gyroscopes and accelerometers is discussed, and the effect is calculated of certain errors in the components. Means for combining inertial navigation with radio navigation aids are outlined, and it is shown that this gives an effective memory over periods in which the radio aid may be inoperative, a heavy filtering of the radio-aid output without introducing lag and loss of information, and interpolation between outputs of a low-data-rate system. The performance requirements for gyroscopes and accelerometers to obtain this can be much less stringent than for pure inertial navigation.

Friday, 28th March

Session 3. RANGE AND BEARING SYSTEMS

General Aspects of Short-Range Rho-Theta Systems *Paper No.* 2578: *Part B*

C. E. STRONG, O.B.E., B.A.

The paper recapitulates in simple terms the principal processes used in rho-theta systems, namely azimuth transmission, distance measurement and direction finding. An outline is then given of Tacan, illustrating the application of the processes in an established system of particular present interest.

Further illustrations are taken from V.O.R. technique, in particular, an experimental system known as V.O.R.A.C.

Finally the author suggests that the most generally applicable form of a rho-theta system would be one giving the distance and bearing indication both in the air and on the ground, and the paper ends with speculations on the application of secondary radar technique to such a purpose.

Tacan: A Navigation System for Aircraft *Paper No.* 2586: *Part B*

W. L. GARFIELD

Tacan is the latest form of rho-theta navigation system for aircraft and embodies certain novel features.

The system characteristics are briefly described and a short history of its beginning and development is given.

Basic principles of operation are followed by a description of the apparatus required, and the advantages of the system for bad site operation are discussed. Additional facilities are described, such as data link and approach aid integrated with Tacan, and a summary of the system advantages is given.

Current Direction-Finding Practice *Paper No.* 2579: *Part B*

H. G. HOPKINS, B.SC., PH.D., *and* B. G. PRESSEY, M.SC., PH.D.

Direction-finding practice in Britain is reviewed over the band 10 kc/s–400 Mc/s; the survey is restricted to land-based systems. Current applications are outlined, the factors affecting accuracy are discussed with particular reference to those concerned with propagation, and equipment is described.

The applications are numerous, ranging from location of thunderstorms at the lowest frequencies to widespread aeronautical uses at the highest frequencies. Over the lower parts of the frequency range the effects of the ionosphere on accuracy have to be borne in mind in many of the applications. In the v.h.f. and u.h.f. bands these limitations are absent for short-range working and the accuracy is determined largely by site and instrumental properties.

The majority of direction-finders in current use have fixed aerial systems, the most common being the Adcock type. At the lower frequencies, however, loops are used, and wide-aperture systems having circular arrays of aerial elements are finding application at the higher frequencies. Regarding the display of bearing information, although some use is still made of the aural-null method, automatic presentation of the bearing either on a meter or on a cathode-ray tube is generally employed. For aeronautical purposes in the v.h.f. and u.h.f. bands, where development has been particularly marked, remote control of the equipment and remote display of the bearings (on a number of frequencies simultaneously, if required) are of increasing importance. A description is

included of automatic position-fixing systems for which these remotely operated instruments are especially adapted.

The Practical Evolution of the Commutated-Aerial Direction-Finding System *Paper No.* 2569: *Part B*

C. W. EARP, B.A., *and* D. L. COOPER-JONES, B.SC.(ENG.)

The paper sets out to show how the more fundamental problems encountered in the development of the commutated-aerial direction-finding system have been solved during a long-term development plan.

Reasons are given for the choice of a circular array of aerials, which are commutated sequentially to the receiving equipment. It is shown how such an arrangement permits great economy in the number of aerials required for a given system performance, maximum adjacent aerial spacing being much larger than might at first appear permissible, and the method for computation of the signal bearing is described in some detail.

Significant features of the development are described, particularly where problems are peculiar to the system, such as realization of adequate selectivity despite aerial commutation and the avoidance of the effect of aerial interaction.

Finally the authors describe practical circuits for signal processing and demodulation, and for the display of bearing, and it is shown that the solutions adopted should permit realization of the performance predicted by theoretical study some 10 years ago.

Session 4. AIRFIELD AND HARBOUR APPROACH

A Survey of Approach and Landing Aids *Paper No.* 2589: *Part B*

W. J. CHARNLEY, M.ENG.

Various all-weather approach aids for aircraft are reviewed briefly, with reference more to the facilities they provide and their operational limitations than to their detailed design.

Certain aspects of the British Instrument Landing System are discussed and the principles and advantages of automatic I.L.S. approaches in bad weather are outlined. It is shown that there is little hope of extending, with safety, any system of blind-approach aid plus visual landing to operating limits lower than about 150 ft cloud base and 500 yd slant visibility.

It is concluded that the next major step must be a completely blind landing without visual reference, and promising solutions to the problem are indicated.

Precision Approach Radar *Paper No.* 2581: *Part B*

G. J. MOORCROFT, M.SC.

The paper discusses the operational and technical requirements for a precision-approach radar (P.A.R.) equipment. These requirements may be met by a variety of different practical designs. One such design now in production is described in detail and the principles governing the choice of design are explained.

A Survey of Harbour Approach Aids *Paper No.* 2574: *Part B*

A. L. P. MILWRIGHT

The paper describes the various systems of harbour-approach aid which are either in operation or in development. The former consist of radar reflectors, surveillance radar equipment and microwave course beacons, and the latter include radar beacons, transmission of surveillance pictures to ships and radar identification.

The Application of Radio Altimeters to Aircraft Approach and Landing *Paper No.* 2587: *Part B*

M. P. G. CAPELLI, A. E. OUTTEN, *and* K. E. BÜCKS

The principles of operation of pulse and frequency-modulated altimeters are described, and typical examples of the two types of equipment are used to illustrate the text. The practical applications of these equipments in aviation are listed, with particular emphasis on the modern requirement for an altimeter capable of assisting the approach and landing of an aircraft in conditions of poor visibility.

Session 5. MARINE AND GROUND RADAR

Advances in Ground Radar for Civil Aviation *Paper No.* 2580: *Part B*

E. EASTWOOD, PH.D., M.SC., *and* C. D. COLCHESTER

The need for ground radar for civil aviation is discussed, and also its growth during the last ten years, first in the terminal areas, and more recently to assist control on the airways. Typical radars designed for civil use are next described and possible ways of meeting future requirements. Advances in techniques are then mentioned, and it is shown that the problems of radar data generation and transmission are largely solved. How to make best use of these data in the field of air traffic control is shown to be the subject of active study.

Survey of Recent Development in Marine Radar *Paper No.* 2573: *Part B*

A. L. P. MILWRIGHT

The survey is of the design of the various parts of a marine radar set, and suggestions are made for the future development of radar equipment of much higher discrimination, in order that the aspect of other vessels may be seen by the aspect of their echoes in relation to the heading mark of the ship.

A Mathematical Analysis of Collision Course Prediction by Doppler Radar *Paper No.* 2655: *Part B*

H. R. WHITFIELD *and* C. M. CADE

The usefulness of radar plotting, as at present practised at sea, may be considerably enhanced by the application of a proposed Doppler radar technique which gives instantaneous measurement of relative velocity components and facilitates the plotting process. This paper sets out the equations of relative motion, and shows how they are related to the observable Doppler frequency. In the system proposed, the range and bearing of the target are given by a conventional radar p.p.i., from which change of bearing may also be determined. The Doppler radar equipment gives an immediate measurement of the radial component of relative velocity and the derivative of radial velocity: from these data the course and speed of the target may readily be determined—using an automatic computer if so desired. Possible errors in deducing the true course and speed of the target are examined, and the mode of operation and principal design parameters of a suitable Doppler radar are discussed.

FACTORIES FOR SPECIAL COMPONENTS

725.4 : 621.3

Modern electronic components, such as semi-conductors and quartz crystals, raise unique manufacturing problems. Conditions obtaining in the research laboratory must be duplicated for mass production, highly corrosive and toxic chemicals disposed of, and unprecedented standards of purity maintained. For this work, new air-conditioned buildings are required with many special features. Mr. Rolfe, who is Managing Director of both Cathodeon Crystals Ltd. and the Newmarket Transistor Co., outlines some of the problems to be considered in the siting and design of such factories. The article is based on his Chairman's address to the Cambridge Radio and Telecommunication Group on the 8th October 1957.

N. C. ROLFE, B.SC., MEMBER

In these days, when the requirements of specialized radio components are becoming ever more exacting, the conditions under which they have to be manufactured become increasingly complex, and it is now apparent that the electrical engineer himself must play a great part in the design, specification and construction of factory buildings in order that the requirements of the product can best be achieved. On the other hand, this exercise can itself be so specialized as to fall outside the experience of the engineer concerned, who must therefore fall back on the help and advice of experts. In this article I am attempting to set out some of the problems and give examples of their solution in the hope that it will broaden the engineer's outlook in this most important field. To simplify matters I have recorded various problems and difficulties associated with different building projects for which my colleagues and I have been responsible.

Choice of Site

The most important decision was always the choice of site, which depended on the following various factors.

Availability of Labour. In all cases it was essential to have a fairly accurate assessment of the labour force needed, both initially and for several years ahead. This entailed a detailed knowledge of the type of labour, i.e. male and female operating staff, supervisors, foremen, engineers, technicians, administration staff, accounting clerks, etc.

Where we were concerned with setting up in an already thriving industrial area, consideration had to be given to providing better facilities than our neighbours in order to attract staff. Facilities concerned were physical, psychological and cultural, since it seemed essential that people should *want* to work for us, although the precise reason for wanting to do so was not necessarily important.

If the factory was to be built near a village, the choice of village depended on its accessibility and on the nature of the activities normally carried out in the locality. We found that when dealing with an agricultural village, the reaction to the incursion of industry follows the pattern:

Stage 1. The villagers hate the thought of it.

Stage 2. They get used to the idea and realize that it does not interfere to the extent anticipated.

Stage 3. What on earth would they have done without the economic advantages the local industry has brought them?

It was found that, in spite of our nationalized education system, there exists a vast difference between the levels of intelligence of town and village labour, and this required the establishment of completely different systems for training and supervision.

Transport. This aspect needs little emphasis except to point out that in the component industry the problem of dispatching the finished product is far outweighed by the need to ensure delivery of raw materials, capital plant to the building, and employees to and from work.

Contour of the Land. Included under this heading is the nature and composition of the soil, together with the slope and general contour of the ground on which it is proposed to build. This is more important than is at first realized since such problems arise as:

(*a*) the expense of moving large masses of earth from one point to another,
(*b*) the difficulty of digging foundations on a rock base,
(*c*) the possibility of unsuspected subsidence,
(*d*) the question whether the site drains naturally, and
(*e*) the possible need to build on piles.

It must not be assumed that a level site is the most desirable; in fact one of the most successful ventures—a quartz crystal laboratory—was built on a sloping site (Fig. 1). As can be seen, this has not only functional but aesthetic advantages, of which full use has been made by the architect. At a transistor factory in Newmarket, on the other hand, the site was low-lying and level; the building design lent itself to a completely different treatment, and special action had to be taken to minimize a tendency for the site to become waterlogged.

Air Contamination. In both town and village, a survey was made of the nature and proximity of neighbouring industries with a view to ascertaining the possible effects such industries would have on our product by their pollution of the atmosphere. A study of the prevailing winds proved invaluable. In towns, hazards such as gasworks and chimneys emitting high-sulphur-content flue gas can do excessive damage to components using silver either in a process or as a finish. An equally dangerous hazard in both town and village can be the gases given off by nearby rivers owing to uncontrolled effluent

1 *Quartz-crystal laboratory at Linton, Cambridge*
The aesthetic advantages of a sloping site can be seen.

discharge. When siting the transistor factory, care had also to be taken to ensure that airborne grit and dust from nearby industries was avoided. It is interesting to note that serious process difficulties arose in the manufacture of transistors while a new extension of the factory was being built. This was not detected at the time, but analysis of minute dust particles present in the production lines which had escaped the air-conditioning units showed an exceptionally high cement-dust content. Completion of the building work gave rise to a considerable increase in production efficiency.

Trade Effluent. Control of trade effluent is essential to safeguard other industries, your own personnel, the inhabitants' livestock, and the agriculture of the neighbourhood. The most insidious aspect of this is the disposal of liquids. The usual tendency in these civilized days is to dispose of what you dislike or discard it down the drain, and having done that to forget all about it. It must be remembered that drains are connected to sewers, the outfall of which passes through filter beds. If the bacteria in filter beds are killed due to poisonous liquids in the sewer very serious health hazards to population and animals arise. This point had special significance when building the transistor factory at Newmarket, where, of course, the prime industry is that of horse breeding and racing. In consultation with the local authorities a code of practice has been established whereby trade effluent has to be declared, a degree of dilution guaranteed and neutralizing agents introduced where necessary. This practice is enforceable by means of legal agreement and may be subject to inspection.

Local Relationships. There are many matters of which consideration will do much to establish and maintain good relations with local inhabitants and authorities. For example, in village areas some people do not like looking out on factory buildings, and this often leads to requests for screening hedges, trees or fencing. Again, village water, electricity and gas supplies may be such that the factory's peak demand will embarrass the villagers.

Road and pedestrian entrances and exits should be arranged so that traffic is not impeded, and the noise of employees coming to and from work, particularly under evening or night-shift conditions, should be reduced to a level which does not cause inconvenience.

It has always proved both desirable and sensible to advise the local councils and authorities at the earliest possible stage of our problems and intentions. In many cases their experience has offered immediate solutions to difficulties, and consultation has ensured future co-operation and understanding.

Finally under this heading is the question of housing for employees. From some points of view, industries built in what are known as new towns have a distinct advantage, but the author's experience is that, in both village and country town, co-operation with the local authorities has led to constructive, positive action in the building and allocation of houses and flats.

Design of Building

Having studied all the above points and selected the site, one must go through a lengthy procedure in order to obtain the relevant permissions, planning approval, etc. Much can be done by way of co-operation with the authorities to reduce this time factor.

2 *Junction of lateral and longitudinal ducts in drainage grid and method of laying vulcathene piping*

3 *Filters for air-conditioning system*
Illustrates method of unit cleaning and maintenance.

Turning to those aspects of building design which depend solely upon the nature of the particular component itself, I have confined my examples to internal drainage, supply services and cleanliness as applied to quartz-crystal and transistor factories. These are by no means the only points for consideration but they are felt to be of major importance.

Internal Drainage. In the manufacture of quartz crystals and transistors, large quantities of toxic, poisonous, corrosive and explosive liquids have to be drained away safely from the process benches. When specifying the design of the buildings, we had to consider the various following alternative methods of disposal:

(1) The discharging of liquids from each bench into separate tanks, which could in turn be removed and emptied. This method was quite unsuitable, since large quantities were involved, and the accident hazard was excessive.

(2) The location of all the processes using liquids around the external walls, so that the waste could be drained into a common pipe through traps and neutralizers into the main external drain. This method was ruled out on the grounds that, although perfectly practicable, it resulted in an uneconomical and inflexible bench and process layout.

(3) The construction of a drainage grid in the floor during the building of the factory. This method offered the maximum flexibility, and was the one chosen.

The system selected consisted of longitudinal and lateral ducts equally spaced along the factory. Proper planning and design ensured that sufficient fall was obtained from any position over the floor area, and inlets to the system could be effected from any bench. One other advantage was that other services could be accommodated in the ducts, with consequent improvement in flexibility and tidiness.

The drainage pipes laid in the ducts were made of vulcathene, which could withstand the harmful effects of any of the liquids used. Installation and maintenance of this piping proved a simple matter, as can be seen in Fig. 2. At the point where a pipe entered the external drainage system, arrangements were made to ensure that the correct amount of water was automatically added to ensure the statutory dilution. In the quartz-crystal laboratory, located in a village, water supply presented a problem, and in order to reduce inconvenience to the villagers arrangements were made to install a large-capacity storage tank from which the laboratory's demands during the day were met and which was replenished at night, when the village demand was low.

Supply Services. Electricity and telephone services proved no difficulty at all, but this was due to the fact that, although considerable cabling and installation work had to be carried out, the authorities concerned were brought into the picture at the early planning stage.

Gas supplies proved to be a special problem at both town and village locations, but for very different reasons. In the village there were no public gas supplies; any gas required had to be of the bottled or cylinder variety, which involved problems of transportation, installation and purity control.

In the town, coal gas was available as a public supply, but the demand for special gases was enormous. They were primarily required for semi-conductor processes and had to be controlled for purity to a fantastically high degree. Obviously this involves great vigilance.

4 *Part of general air-conditioning plant*
Clean air is conveyed to all parts of the room by outlet ducts equipped with air-diffuser plates. Radiant heater panels give flexibility of floor area.

Cleanliness. The word 'cleanliness' is rapidly becoming one of the most used words in the component industry. The need for cleanliness itself is perhaps responsible for the most significant changes in building design and factory control, particularly as applied to semi-conductor work. There are two fundamental aspects of this problem: (1) how to make your product clean, and (2) how to keep it clean after cleaning it.

The first is an essential part of the technique of processing and making components such as transistors and is not, therefore, considered to be in the scope of this article. However, how to keep it clean is a factory administration problem worth considering; thousands of pounds have been, and are being, spent on its study.

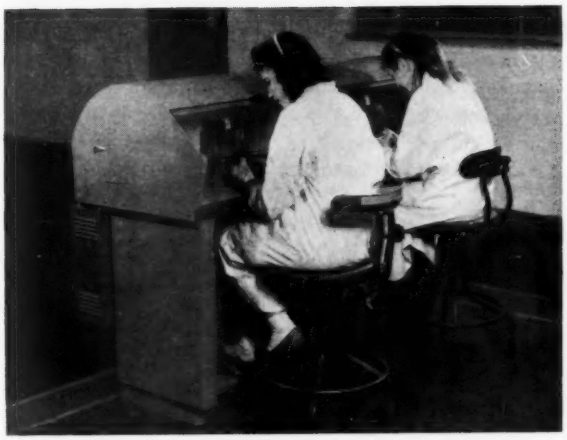
From a 'mechanical' point of view, it was realized that factory staff would bring in considerable quantities of dirt on their clothes, shoes, hair and person. It was therefore necessary to provide adequate facilities for overalls, overshoes, headgear and gloves, all made of lint-free materials. These, in turn, had to be kept scrupulously clean and replaced regularly. A certain amount of discretion had to be exercised in this respect, and the complete kit was issued only where vital.

Floors had to be surfaced with a material which could be cleaned easily and withstand the chemical action of acid, oil and solvent, yet was easy on the feet, and the best compromise proved to be good-quality linoleum.

It was considered essential to achieve a high standard of clean air throughout the process areas, but the need for general humidity control did not appear to be necessary. Air-conditioning did, however, involve special attention being paid to roofing, roof linings, windows, doors, heating systems, lighting and ledges. Examples of the systems used and precautions indicated above are illustrated in Figs. 3 and 4.

Where specific process or assembly lines required a very special degree of cleanliness control and also demanded low levels of humidity, two additional stages were added. Stage one was effected by means of the specially designed hooded benches shown in Fig. 5, which prevented any possible contamination from direct dust. They could be fed with clean dry air or special gas and were equipped with electrostatic cleaners. Stage two involved the design and construction of totally enclosed bench units (Fig. 6) fed with dry air and equipped with a system of tunnels, so that components never came out into the ordinary air until hermetically sealed.

Systems such as these do involve a certain amount of discomfort to personnel, since, for example, it is almost impossible to wipe one's nose when one has both hands gloved and passed through a double rubber air lock.

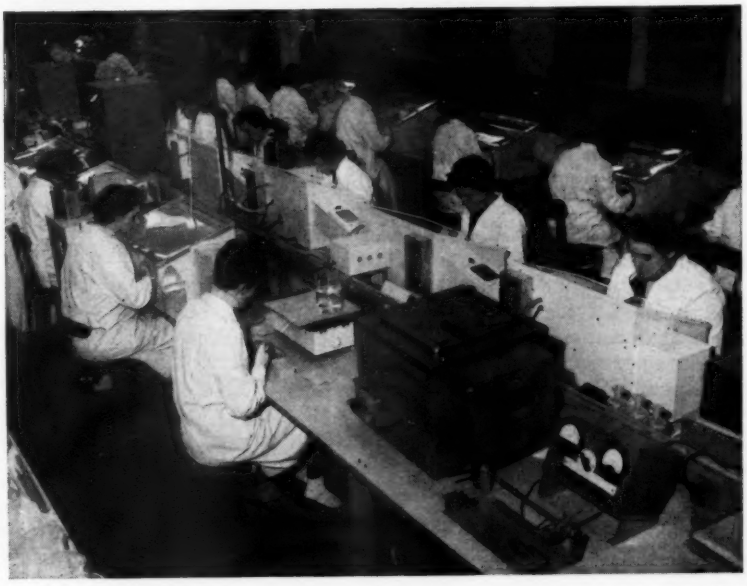


5 *Hooded bench unit*
Components are protected from direct contamination by dust.

Psychological training of personnel proved necessary to ensure that such discomforts and irritations soon gave place to a fervent desire to keep things clean at all costs. This is a difficult exercise in the transistor industry, since the component parts are so fantastically small that it is difficult to *see* them, let alone handle them and keep them clean.

In conclusion, there is no doubt that the need for greater cleanliness control in component factories will bring with it a changed outlook from the operating and

6 *Dry-air units linked together by tunnels*
This system ensures clean air under humidity-controlled conditions, and continual protection of the component until it is hermetically sealed.



supervising staff of these organizations. At present the standard of house-keeping in the works is far higher than anything likely to be found in the home—indeed in certain instances higher than that expected in hospitals. The sociological effects of this are a little difficult to foresee, and whether personnel are likely to become more, or less, susceptible to disease and epidemics under these conditions remains to be determined. In any case, cleanliness control is the first step towards quality control, which is one of the keys to productivity.

PROTECTIVE MULTIPLE EARTHING

621 316.99 : 621.316.13

The safety of electrical installations in rural areas has been the subject of inquiry for many years, and one comparatively recent result has been the increasing use of protective multiple earthing in Great Britain and other countries. The author, who is with the North Western Electricity Board, has been concerned with installing and testing p.m.e. on distribution systems in the Board's Area. His findings were published in a paper (No. 2420) entitled 'Earthing of Low- and Medium-Voltage Distribution Systems and Equipment', on which the present article is based. Mr. Mather read his paper before the Supply Section at Savoy Place on the 20th November 1957, and it is republished this month in Part A of the Proceedings.

F. MATHER, MEMBER

PROTECTIVE multiple earthing, often abbreviated to p.m.e., is applicable to low- and medium-voltage distribution systems. It involves the connection of the neutral conductor with the general mass of earth at several points along its route. The object of this short article is to explain why, on many distribution systems, the use of this method can ensure reasonable safety without wasteful expenditure. It is particularly useful for improving the conditions on existing systems where the methods of earthing are unsatisfactory.

It should be mentioned at the outset that the Electricity Supply Regulations, 1937, require that, unless otherwise approved, one point and not more than one point of each low- or medium-voltage distribution system shall be connected with earth. Thus p.m.e. cannot be employed in Great Britain without authorization from the appropriate Government department in respect of each system concerned. A 'system' may, for the present purpose, be assumed to comprise a distribution transformer and the low- or medium-voltage distributors and branches to which it affords supply.

It is made clear in the 13th Edition (1955) of The Institution's Wiring Regulations that protection against dangerous earth-leakage currents can be obtained in three ways:

(1) By the use of 'all-insulated' or 'double-insulated' appliances.

(2) By using over-current protection and ensuring that the 'earth-fault loop' between the supply transformer and the non-current-carrying metalwork of all electrical equipment is of suitably low impedance.

(3) By using some form of earth-leakage protection in conjunction with a connection, which may be of relatively high impedance, between the non-current-carrying metalwork of all electrical equipment and the general mass of earth.

Method (1) is limited to certain types of equipment which lend themselves to 'all-insulated' or 'double-insulated' construction.

Method (3) has been dealt with extensively in other publications and is outside the scope of these notes. It may, however, be mentioned that earth-leakage protection has certain advantages where speed of operation and sensitivity are of greater importance than cost, simplicity and freedom from maintenance.

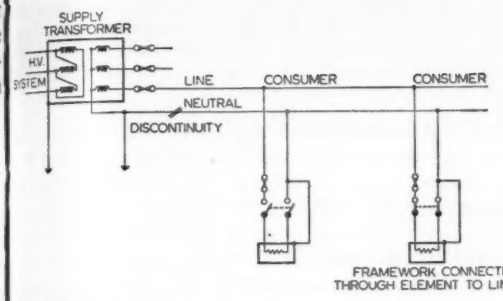
The most commonly used method is (2), and in an underground distribution system comprising lead-sheathed cables, there is seldom difficulty in providing an earth return path of suitably low impedance. This is done by bonding the neutral point of the supply transformer and the frames of all apparatus to the lead sheaths.

It has been common in the past for consumers' appliance frames to be bonded to the metal pipes of a public water-supply system, and thus connected with the general mass of earth. The earth-fault loop is completed by the earthing of the transformer neutral point.

Whilst this method has been fairly successful, its period of usefulness has come to an end, owing to the introduction of non-metallic water mains and service pipes and owing to the need for lower earth-fault-loop impedances. It is now common for 60 amp service fuses to be installed at domestic premises, and, with a supply voltage of 240 volts, the earth-fault-loop impedance should not exceed 1·33 ohms for compliance with I.E.E. Wiring Regulation No. 406.

Such low values of earth-fault loop impedance are normally obtainable only by some form of metallic connection from the neutral point of the supply transformer to the frames of all apparatus.

In rural areas, where supply is usually by overhead line, this metallic connection can be provided by running a continuous overhead earth wire, but this has certain disadvantages. It is an unwelcome addition to the cost of the distribution system, and cannot always be readily added to the many existing systems where earthing



1 *Neutralizing*

arrangements are in need of revision. Perhaps the most serious disadvantage is that, if a break should occur in the continuous overhead earth wire, there would be nothing to indicate that this had taken place. Then, when the first earth fault occurred in an appliance, the frames of all apparatus beyond the break would become alive, and danger could result in the premises of many consumers.

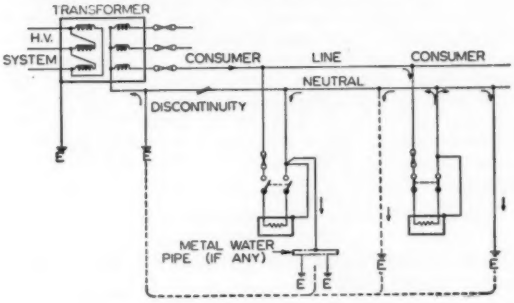
The whole question of safety of consumers in rural areas received the attention of the Electrical Research Association many years ago, and in 1937 and 1941 reports on the subject were published in the *Journal* of The Institution.* It was shown that with certain safeguards, the neutral conductor could be made to function as an earth-return conductor, so that the extra cost and disadvantages of an additional overhead conductor could be avoided.

The basic method is shown in Fig. 1, in which all consumers' earth-continuity conductors are joined to the neutral at the point of service entry. This simple method, known as *neutralizing*, would be ideal but for the possibility of a discontinuity in the neutral conductor. If this occurred the frames of all appliances beyond the break would be made alive through the elements of any appliances which happened to be in use.

To guard against this danger, the reports of the Electrical Research Association proposed that multiple earthing of the neutral conductor should be permitted, so that any break which might occur in the neutral would be shunted by a path through the earth, as shown in Fig. 2. Specific recommendations were made as to the type, location and resistance values of the earth electrodes required. These recommendations formed the basis of the first Protective Multiple Earthing Regulations issued in 1940 by the Electricity Commissioners with the concurrence of the Postmaster General. It was, of course, necessary for the Post Office to ensure that their communication systems would not be adversely affected by interference from nearby power lines. Such interference might take the form of noise from harmonic currents in the power lines, since the sum of the currents in the phase and neutral conductors might not be zero. Furthermore, there was the possibility that earthed Post Office circuits might suffer noise or other forms of interference owing to potentials set up between different points in the earth by a proportion of the power system current following paths through the earth in parallel with the neutral conductor. Up to the present, the Post Office has not experienced trouble from these causes as a result of the use of p.m.e.

Unfortunately it proved either impracticable or too costly for supply authorities to take advantage of these Regulations, and very little use was made of protective multiple earthing in Great Britain.

Later, the Electrical Research Association gave much attention to the economics of earthing. In 1949 they recommended certain relaxations of the original P.M.E. Regulations with a view to making the method more practicable and less costly, without greatly affecting the protective efficiency. The Ministry of Fuel and Power, again with the concurrence of the Postmaster General, acted on the recommendations, and the present-day P.M.E. Regulations appear as Appendix F of the Wiring Regulations, 13th Edition (1955).



2 *Protective multiple earthing*

The main features of the system are:
a An earthing electrode for the framework of the h.v. apparatus. Its resistance is low enough to pass twice the operating current of the h.v. circuit-protection device.
b A neutral earthing electrode of unspecified resistance outside the resistance area of a. This may be omitted if there are two or more distributors.
c An earthing electrode of unspecified resistance at (or near) the end of the neutral of each distributor or branch.
d Additional earthing points as may be necessary to reduce the total resistance from neutral to earth to 10 ohms.
e A connection from each consumer's earth-continuity system to the neutral at the service entry.
f Fuses in the phase conductor only.
g A neutral conductor of the same material as, and of not smaller cross-section than, the associated phase conductor.

There were still certain doubts about safety under broken-neutral conditions, and the author read a paper before The Institution on the 20th November 1957 describing tests carried out by the North Western Electricity Board on typical systems with broken distributor neutrals and service neutrals. The tests involved numerous voltage measurements at farm and cottage premises to establish the shock risk, and to determine how measured values compared with those calculated from a knowledge of electrode resistances and

* Taylor, H. G.: 'The Use of Protective Multiple Earthing and Earth-Leakage Circuit-Breakers in Rural Areas', *Journal I.E.E.*, 1937, **81**, p. 761, and 1941, **88**, Part II, p. 415.

consumers' loads. Fig. 3 shows a test in progress and indicates how voltage measurements were taken by means of high-resistance voltmeters and plates or probes at points where shock might be experienced. Tests were taken, for example, between the bonded frames of consumers' apparatus and floors, walls, fireplaces, etc. The illustration also shows the type of variable resistance employed to simulate various connected loads at the consumers' premises, since the shock risk is partly determined by the parallel resistance of elements connected to the supply mains beyond the neutral break.

The main points emerging from the series of tests are as follows:

(1) The voltages measurable within the premises are, in general, very much lower than those measured with respect to a remote reference earth electrode. This is due partly to the fact that the potential of the whole fabric of the structure tends to rise with respect to true earth when current passes through the local electrode. It is a valuable factor which limits shock risk at the premises.

(2) Careful attention to the disposition and resistance values of earth electrodes can minimize risk if neutral breakage should occur. In general it appears advantageous to concentrate earth electrodes, as far as practicable, at the near and remote ends of distributors. The object is to equalize the resistance from neutral to earth at each side of a neutral break wherever this should occur.

(3) The provision of an earth electrode, even of relatively high resistance value, at each consumer's premises, is a valuable safeguard in case the neutral of a service line should break. In most isolated rural premises there is a metallic water supply pipe which makes an effective electrode and avoids the need for further expenditure.

(4) It is most important that, at each consumer's premises, the frames of all electrical apparatus should be carefully bonded and that all other metalwork in the vicinity should be connected to the earth-continuity system. If this is done, the possibility of severe electric shock is kept to a minimum.

Although the tests described above have been carried out to provide information, it should be explained that with modern line construction the danger of neutral breakage is slight. Not a single breakage of a distributor neutral or service neutral on a p.m.e. system has been recorded by the North Western Electricity Board since the method was first used in 1949. The Board had, at the end of 1956, a total of 1 242 separate systems employing p.m.e. and supplying 5 370 rural consumers.

In the discussion which followed the reading of the author's paper, tribute was paid to the Ministry of Power and to the Post Office for their helpful attitude in permitting the gradual relaxation of regulations when accumulating experience showed that this could be done with safety. The North Western Electricity Board were congratulated on their progressive efforts to achieve safety by undertaking the co-ordination of their own earthing arrangements and those of new consumers.

It was emphasized that p.m.e. is unique among earthing systems in that it provides a second line of defence. Nevertheless, with good design and workmanship, the first line of defence, namely a neutral conductor of substantial cross-section, should rarely fail. Thus, the view that p.m.e. is now an efficient and economical system seems fully justified.

3 *Voltage testing in a farm at points where shock might be experienced under broken-neutral conditions*

On the table on the right is the variable resistor used in the tests. Each observer can, on receipt of instructions, connect between phase and neutral a resistance of 60, 30 or 20 ohms, corresponding to a load of 1, 2 or 3 kW at normal supply voltage.

Summary

Protective multiple earthing is applicable to low- and medium-voltage distribution systems. It involves connection of the neutral conductor with earth at several points. The method is economical and is particularly useful for improving earthing conditions on existing distribution systems.

One important feature of p.m.e. is that the neutral conductor of the distribution system forms a metallic return for leakage current when earth faults occur on wiring or equipment. Thus the earth-fault-loop impedance is low, and the fault current is sufficient to operate simple over-current protection.

Another important feature of p.m.e. is that, if a break should occur in a neutral conductor, it is shunted by earth paths. With modern construction, however, breakage of neutral conductors is rare, and the second line of defence formed by multiple connection with earth is seldom needed. Tests have shown that compliance with the P.M.E. Regulations ensures an adequate degree of safety even if neutral breakages do occur.

THE KELVIN LECTURE MEETING

Sir Harry Melville gives the Forty-ninth Kelvin Lecture

Mr. H. T. Young and Sir Gordon Radley receive Institution Honours

THIS year the day of the Kelvin Lecture fell early. For the traditional time towards the end of April will see the President and Secretary in Canada nearing the end of their Commonwealth tour. Because of this event, too, the agenda of the afternoon's Council meeting was of almost record length, and Members of Council must be forgiven if they showed slight traces of weariness as they entered the Lecture Theatre at 5.30 p.m. But the President did not look in the least tired, despite the arduous job of controlling a three-hour meeting of 50 prominent engineers, and his smiling and serene face as he took the chair in the Lecture Theatre put all the audience at their ease.

The audience was small for a Kelvin Lecture—but it would not have been if many of those who had stayed away knew what they were missing. For apart from the interest and corporate pleasure in the awards to two very distinguished engineers, there was an erudite and fluently delivered lecture by the distinguished chemist, Sir Harry Melville, who is Secretary of the D.S.I.R. and who only five weeks previously had been made a Knight Commander of the Bath. Possibly the short title of the Lecture—*High Polymers*—confused members, yet even the writer of this article suspected that the term included plastics, and plastics are surely a subject in which there is once again growing interest. Alternatively, the earlier date may have caught members unawares. But whatever the cause of its limited size, the audience present—about average for a normal Ordinary Meeting—gave ample evidence of its appreciation of Dr. Melville's lecture.

After welcoming a number of new Corporate Members with the brief, and now almost traditional, ceremony, Mr. Goldup proceeded to the presentation of a Certificate of Honorary Membership to Mr. H. Young, PAST-PRESIDENT, who was elected by the Council on the 7th November 1957 to receive this honour.

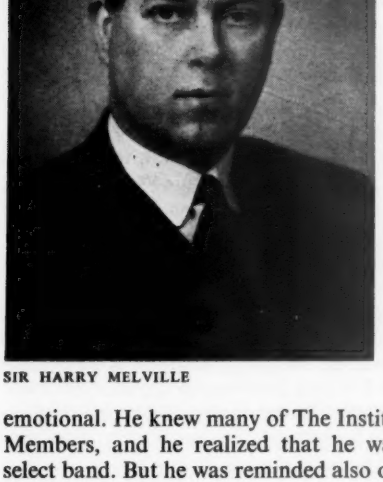
The President recalled that Mr. Young was born near Buckingham in 1888 and received his technical education at the South Western Polytechnic, and his early practical training with Rawlings Bros. During the last fifty years he had been associated with the organization which bears his name as one of its originators, and had seen this expand into the present group of six interrelated companies concerned with installation, of each of which he is Chairman.

Mr. Young's early interests lay mainly in domestic installations, but his field of activity had extended to installations in every type of building in this country and oversea. He joined the Illuminating Engineering Society in 1913, and served three years on their Council, receiving their first award of the Leon Gaster Premium; he became a member of the Electrical Contractors Association in 1917. From the time of the establishment of the Electrical Development Association, Mr. Young took an active part in its work, representing The Institution on its Council for a period of five years. He was instrumental in ensuring the full participation of the electrical industry when the establishment of a Building Centre in London was considered in 1930.

Mr. Young served on the Council of The Institution from 1927 to 1930 and he was Vice-President from 1932 to 1935 and President in 1936. While President, he represented The Institution at the Coronation of King George VI in Westminster Abbey.

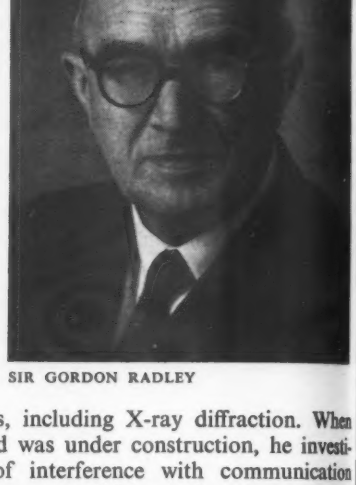
It was largely through his sustained efforts that the Installations Section (later to become the Utilization Section) was formed, and he became its first Chairman. He also played a most active and successful part in helping to establish the *Students' Quarterly Journal* in 1930, a venture that was not acceptable to all Members of Council at the time. Since 1924, he has served on many Institution Committees and has taken a special part in the activities of the Local Centres and the Student Sections, being appointed Council member of the London Students' Section in 1928 and a member of the Local Centres Committee in 1930. In 1934, he presented a trophy, known as the Young Trophy, for which student members of the three major engineering Institutions compete annually in various sporting events.

When the President had finished speaking, Mr. Young signed the Book of Honorary Members and Faraday Medallists and received a Certificate of Honorary Membership from the President's hands. He then came to the microphone to speak, a happy smiling man who did not look his age. He must have been particularly pleased that his son was sitting in the audience on this great occasion. In replying to the President, he said how appreciative he was that the President and the Council had done him this honour. He felt immense pleasure and satisfaction which he found difficult to describe in words, without becoming too sentimental or



SIR HARRY MELVILLE

MR. H. T. YOUNG



SIR GORDON RADLEY

emotional. He knew many of The Institution's Honorary Members, and he realized that he was joining a very select band. But he was reminded also of other Honorary Members whom he had seen accept the certificate in the theatre, men who had given him good advice and great encouragement in his younger days—and who were no longer alive. They were great men, many of them, and great pioneers. His thoughts had been with them as he sat listening to the President.

Mr. Young was glad that the President referred to the side of the industry in which he had spent much of his life. In the early days people connected with installations were rightly blamed for causing a bottleneck in development. But since the First World War an enormous amount of work had been done by those responsible for installations and utilization to enable people to use the electrical equipment that had been made available. In that connection, he thought that The Institution itself had done, through its papers and discussion meetings, much useful work; and to-night he recalled especially the valuable activities of the Utilization Section during the previous ten or twelve years. These had made their mark, and The Institution deserved credit for them.

Mr. Young ended by again thanking the President and Council for their kindness.

Next, the President came to the presentation of the Faraday Medal for 1958 to Sir Gordon Radley, K.C.B., C.B.E., PH.D.(ENG.), PAST-PRESIDENT. This award, the thirty-sixth since the Medal was established, was made by the Council on the 7th November 1957.

William Gordon Radley, said Mr. Goldup, was born in 1898; he was educated in Leeds and trained at Faraday House, where he was awarded the Gold and Silver Medals. He joined the Post Office Engineering Department in 1920, and was posted to the Research Branch, where he was to spend the next 29 years. His first work concerned line transmission, but he was soon assigned to materials problems and he specialized in spectrographic techniques, including X-ray diffraction. When the electricity Grid was under construction, he investigated problems of interference with communication circuits, carrying out many field experiments to confirm theoretical studies. For a thesis on this subject he was awarded a Ph.D. degree by London University in 1934.

His primary technical interest then moved to corrosion problems; he took part in an international conference organized by the Bureau of Standards in Washington in 1937, and was co-author of an Institution paper which was awarded the Sebastian de Ferranti Premium in 1939.

Promotion, in 1936, brought responsibility for the development of the long-distance signalling and dialling systems to permit the mechanization of the trunk network; he was soon fully acquainted with the problems and techniques and able to make personal contributions. In 1942, he was again co-author of an Institution paper, which was awarded the Fahie Premium.

The President said that this versatility and ability to specialize in widely differing fields were characteristic of Sir Gordon and had been evident at all stages in his career. They stemmed from a sound appreciation of basic principles and an outstanding ability for hard and thorough work.

In 1939, Sir Gordon became Head of the Research Branch, where he established himself as an authority not only on telecommunication proper but on allied problems involving research and development. He served on a number of inter-Services committees and was responsible for notable improvements in armoured fighting vehicles' communications.

In 1949, he left the field of research and development to become Deputy Engineer-in-Chief of the Post Office, and, two years later, he succeeded Sir Archibald Gill as Engineer-in-Chief. The conspicuous success of these moves again demonstrated his remarkable versatility. For some years previously he had been greatly interested

in repeatered submarine cable systems and, in particular, in the possibilities of a transatlantic telephone cable. It is due to him, more than anyone else in this country, that the epoch-making project completed so successfully in 1956 was put in hand.

In 1954, Sir Gordon established a precedent by leaving the Engineering Department to become a Deputy Director General of the Post Office and the following year he was appointed Director General. Moreover, in assuming these administrative duties, he retained, at his own wish, technical responsibility for the Post Office share in the transatlantic cable. He was co-author of the Institution paper describing the background and plans for the project, which was awarded the John Hopkinson Premium, and, with Dr. Mervin J. Kelly, President of the Bell Telephone Laboratories, he wrote the foreword to the Symposium which was presented jointly to The Institution, the American Institute of Electrical Engineers and the Engineering Institute of Canada, linked together by the cable. This event happily coincided with his year of office as President. In 1955, he and Dr. Kelly were awarded the international Christopher Columbus Communication Prize by the City of Genoa for their work on the cable.

Always a staunch supporter of The Institution—he joined as a Student in 1916—he served on the Committee of the Meter and Instrument Section from 1940 and was its Chairman in 1944–45. He was elected a Member of the Council in 1948, a Vice-President in 1951 and President in 1956. He has served on many committees of the Council.

He was honoured with a C.B.E. for his war services in 1946, with a Knighthood in 1954 and with a K.C.B. in 1956.

At the end of the President's citation, Sir Gordon signed the Book of Honorary Members and Faraday Medallists; Mr. Goldup then presented him with the Faraday Medal and an accompanying scroll. Looking pleased and confident, and thinking perhaps of that unique occasion a year previously when he had chaired the three-nation meeting 'over and about' the cable, he spoke in reply to the President. Sir Gordon said he felt that it was one of those occasions when words were inadequate; but it had given him immense pleasure that his name should be added to the select list of scientists and engineers who had been awarded the Faraday Medal. He was very conscious that with his predecessors the award had generally been because of their own personal contributions to engineering; in his case the award had come to him because of the work of the British and American team who were associated with him in the planning, construction and laying of that first transatlantic telephone cable. It was to their skill and to their effort that he owed his medal.

He had been most fortunate throughout his career both in those from whom he learned and in those with whom he worked. His teacher was Dr. Alexander Russell, who had been, in turn, President, Honorary Member and Faraday Medallist of The Institution. It was a lecture that he gave to the Students' Section, as President, that did much to stimulate Sir Gordon's interest in problems of interference between power and communication circuits.

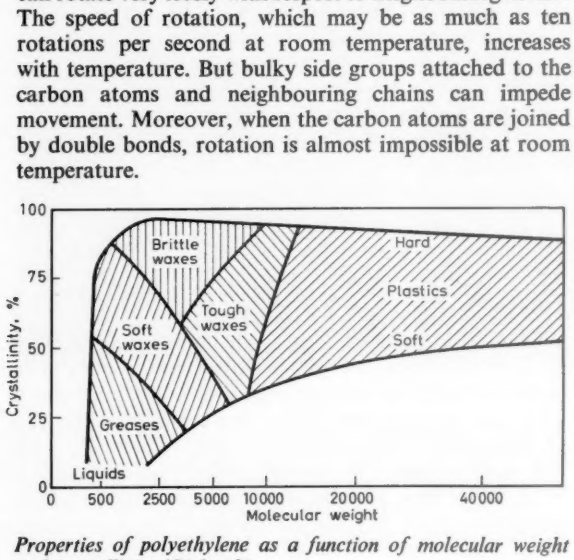
Sir Gordon had been most fortunate also in that he was allowed to spend so much of his official life in research laboratories. His administrative colleagues now told him that this was the way in which he had conserved his energies over the years. Looking back on those most interesting years, he thought that perhaps one of the most significant events was when Mr. R. J. Halsey had constructed in the laboratory the first telephone repeater for underwater working. This was in 1942, and it was a step towards the first transatlantic telephone cable. Then, when they first began to talk seriously of the project in 1952, Mervin Kelly and he had been given the task of assessing the stage reached by repeater development on the two sides of the Atlantic, and they had had to advise whether it was a practical proposition to construct a cable between Europe and America with electronic equipment on the bed of the ocean at intervals. They had recommended that such a cable should be laid. In making that recommendation, they took a calculated risk, and in taking the risk they had to choose what was best in the way of mechanical designs and electronic equipment from the full resources in both countries. Thanks to the untiring efforts of his colleagues, an international team of scientists, engineers and seamen, that project went through. They were now looking forward to 1961 and a new cable to Canada which would have about 90 repeaters and provide 60 circuits in one cable. Sir Gordon ended by thanking again the team that worked with him on the 1956 cable, and the President and his colleagues in The Institution for the great honour they had done him.

The President then asked Sir Harry Melville to deliver the Forty-Ninth Kelvin Lecture on *Relations between Chemical Constitution and Physical Properties of High Polymers*, which, Mr. Goldup said, was a subject of Sir Harry's own choice and one that the Papers Committee thought fitted well into the pattern of Kelvin Lectures.

Sir Harry said that high polymers provided an excellent example of the co-ordination of several sciences to produce materials of interest not only to the chemist who makes them, but also to the physicist and the engineer who use them. Such materials are not particularly new, for rubber and celluloid were discovered in the nineteenth century. The systematic searching for new materials of this kind with specific uses is, however, a quite recent development. Such searching can now be conducted far less empirically than it could be, say, twenty years ago.

The fundamental characteristic of a high polymeric material is its large molecular weight, which may be of the order of a million for linear molecules and indefinitely large for non-linear ones. Another essential characteristic is that the molecules comprise long chains of atoms to which are attached small groups of atoms as side chains. The length and chemical nature of the chains themselves,

and the chemical nature of the side groups, both affect greatly the properties of the materials. When the chain consists wholly of carbon atoms with a single bond between each pair, the atoms and their associated side groups can rotate very freely with respect to neighbouring atoms. The speed of rotation, which may be as much as ten rotations per second at room temperature, increases with temperature. But bulky side groups attached to the carbon atoms and neighbouring chains can impede movement. Moreover, when the carbon atoms are joined by double bonds, rotation is almost impossible at room temperature.



Properties of polyethylene as a function of molecular weight and crystallinity (Richards)

This ability to rotate causes a normal chain to coil up into a random and varying configuration. In a completely free chain, as occurs in an isolated molecule of polyethylene, the ratio of the distance between the ends of the chain to the length of the outstretched molecule may be as high as 50:1, the chain itself containing perhaps 10000 atoms.

There often exist considerable attractive forces—which decrease with increasing temperature—between the long chains in a high polymer; and these forces compete with the other forces tending to make a chain coil up. The result of this competition determines whether a high polymer will turn out to be a rubber, a fibre or a plastic. In trying to produce a new polymer to suit a particular purpose, the approach is usually a combination of logical thought, hunches, accurate observation and patient experimenting.

After giving this introductory information, Sir Harry proceeded to discuss the three classes of high polymers:

1. Rubbers. He said that the reason why rubber can be stretched much more than any other solid was that these molecules are coiled up and the stretching process unwinds them. Normally one is concerned with vulcanized rubber, in which some molecules are cross-linked. Unvulcanized rubber behaves quite differently; if stretched below a temperature of 20° C it crystallizes with alignment of the chains, and does not return to its original shape when the tension is removed. But above 20° C—its so-called melting point—pure rubber rapidly regains its original shape and crystallization and alignment of chains cannot occur.

Rubber-like behaviour is a characteristic of hydrocarbon chains, but the arrangement of the chains and side groups must be such that they do not easily fix together to allow crystallization. For example, the difference between guttapercha and rubber arises from the arrangement of the side groups of atoms about the double bonds in the chain; otherwise the arrangements of the chains of the two molecules are similar. Guttapercha is elastic only above 70° C.

Both natural and synthetic rubbers are elastic only over a limited temperature range, which may be extended downwards artificially by adding small molecules as plasticizers to the rubber to prevent the rubber forming a glass at low temperatures and to ease the movement of the rubber molecules. Extending the temperature range upwards can be done by changing from a carbon to a silicon-oxygen molecular backbone, with various groups of atoms attached to the silicon atoms. This produces polymers of the silicone series, which may be liquids or rubbers. The silicon rubbers have a much larger useful range of temperature than hydrocarbon rubbers.

2. Plastics. What kind of high molecular material results when the intermolecular alignment forces predominate over the coiling-up forces? The answer is plastic or fibrous materials. In plastic materials such as polystyrene, the polymethacrylates, and polyvinylchloride, the intermolecular forces are high, but the molecular chains tend to be asymmetrical, with a random arrangement of side groups; this untidy pattern makes it impossible for the chains to align themselves precisely and for the intermolecular forces to come into full play. The material is non-elastic, isotropic and often glass-clear. The substance flows easily under pressure at moderate temperatures and is ideally suited to manufacturing processes used in the plastics industry.

There is also a class of crystallizing high polymers, in which it is possible to control the arrangement of the side groups in the molecular chains fairly closely. These substances have comparatively high melting points, and the molecular chains have a strong tendency to align themselves. The simplest of them is polyethylene. When prepared at room temperature it consists of a linear chain of carbon atoms with hydrogen atoms attached. It is very similar to a paraffin. Such materials can be heat treated like a metal, so that the molecular arrangement can be changed to give required properties in the substance. A qualitative indication of the effect of this, as well as that of molecular weight, is shown in the diagram. For substances with molecular weights around 10000, the percentage crystallization greatly affects the nature of the material.

The melting point of polyethylene can be substantially raised by exposing it to high-energy gamma radiation.

One of the results is that hydrogen atoms are removed from the chains leaving free radicals behind; the radicals become cross-linked and produce a three-dimensional structure which resists melting.

3. Fibres. Some important properties required in an artificial fibre are that it should have a high tensile strength (say 10 g/denier or 50 kg/mm^2), a high elastic modulus, a resistance to fracture and a high melting point. It should also be insoluble in water, while water absorbent, and have a high abrasion resistance. A polymer to meet these needs must have its molecules oriented along the length of the fibre and must be capable of crystallizing. Fibre-forming molecules are confined to regular structures without bulky side-chains.

It is curious that so far no natural or synthetic fibre has been found with a tensile strength of more than about 10 g/denier. This limiting value seems to be independent of chemical constitution, which might imply that it represented the ultimate strength of this type of material; but, in fact, the strength of the chemical bonds is about a hundred times as great. It is possible that the fibre breaks under tension with the chains sliding past each other and the molecules of the polymer remaining intact. But even on this assumption the actual strengths are less than they should be theoretically. No convincing explanation is known, and it is tempting to speculate that much stronger artificial fibres may be produced in the future.

The melting point of a fibre is extremely important. It must not be too low because fibres usually have to be washed in fairly hot water and to be ironed when used in fabrics. Again too high a melting point is troublesome because many artificial fibres are not soluble and have to be spun by melting and extruding. The melting point is actually determined by the ratio of thermodynamic heat of fusion of the solid to the entropy change in the fusion. For example, Terylene has a heat of fusion of 2·2 kcal and has a value of entropy of fusion as low as 4·0 cal/° C, which gives it a melting point of 265° C.

In the crystalline state geometrical factors have a powerful effect on melting point and tensile strength. With nylon, for example, the extra attraction between the chains arises mainly from what is known as a hydrogen bond. These bonds are spaced regularly along the chain. The strong tendency of the hydrogen atoms to interact with the oxygen of the CO group in a neighbouring chain mainly accounts for the high tensile strength of the nylon fibre.

After the Lecture Sir Noel Ashbridge proposed a vote of thanks to Sir Harry Melville, and this was seconded by Dr. Willis Jackson.

CORRESPONDENCE

STANDARD TERMS: ENGINEERING AND BIOLOGY

From H. W. BAXTER, B.SC.(ENG.), MEMBER*

I cannot let pass without comment the extract from Professor R. O. Kapp's Le Maistre Memorial Lecture that appeared in the *Journal* for January 1958.

Professor Kapp asserts that 'among electrical engineers disagreements cannot arise through different meanings being given to the same words . . . and it is largely thanks to their standardized glossaries that they understand each other so readily'.

It is, of course, true that many terms are defined in standardized glossaries, and there ought not to be confusion if all engineers used the same glossary. But before an engineer acquires the habit of consulting a glossary he is taught to use a dictionary; and he may be surprised, and even bewildered, to find that a glossary assigns to a word a meaning that differs from the dictionary definition.

I would quote as an example the word *flameproof*. The engineer finds from his glossary that *flameproof gear* must withstand an internal explosion and not ignite an inflammable gas which may be present in the surrounding atmosphere; the dictionary tells him that *flameproof* has a much narrower meaning. If the engineer serves on an international committee and consults a French dictionary he will find that the French equivalent of *flameproof* is *incombustible*; but when he points to flameproof gear and asks its designation the Frenchman replies '*antidéflagrant*'. The engineer may then realize that the French term means *not incendiary*; and he may wonder why we did not adopt a similar expression instead of trying to assign to *flameproof* a meaning that goes far beyond the dictionary definition.

In idiomatic English a *dust-free atmosphere* is an atmosphere that contains no dust; to the engineer a *trip-free circuit-breaker* does not mean a circuit-breaker that contains no trip.

Disagreements do arise among electrical engineers through different meanings being given to the same words. *Plug* used to be the part containing the pins; it was later regarded by some engineers as the part containing the contact tubes, and this caused much confusion. Other examples could be quoted.

We seem to be approaching the stage where, having abandoned the commonly accepted meanings of ordinary words, engineers will be unable to converse intelligibly without first indicating in which glossary, or even in which section of a glossary, the meanings of their words will be found.

There is a moral in the remark of my French friend who, when trying to learn English, said: 'When you wind up a watch it goes; when you wind up a business it stops.'

(*More correspondence will be found on p. 219*)

* Mr. Baxter is with the Electrical Research Association. His letter was received on the 3rd February 1958.

SHORT REVIEWS OF PAPERS

On the following pages are some brief review articles based on, and written by the authors of, current Institution papers. The authors have been asked to make these articles, so far as possible, interesting and of appeal to electrical engineers who have no specialized knowledge of the subjects, and the content of the articles is not necessarily confined to the subject-matter of the original papers.

Quality of Television Pictures

A short review of a Radio and Telecommunication Section paper (No. 2540) entitled 'The Relation between Picture Size, Viewing Distance and Picture Quality with special reference to Colour Television and Spot-Wobble Techniques', by L. C. Jesty, B.Sc., Member. The full paper was published individually in February 1958, and it will be republished in Part B of the Proceedings. The author is with Sylvania-Thorn Ltd.

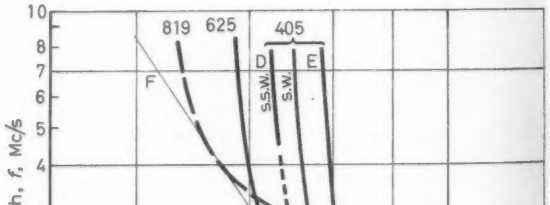
THE QUALITY OF PICTURE-REPRODUCING SYSTEMS, particularly television systems of different standards, has been the subject of discussion and investigation for some twenty-five years. It has been common practice to use teams of observers seated at a fixed distance from the screens of the reproducing systems, to assess or compare the quality whilst various changes are made in the standards of performance. Under these conditions, any improvement in sharpness beyond a certain quality is of little value to the viewer.

In 1951 and 1952 N. R. Phelp and the author published two papers which showed that viewing distance and observer grading were directly related. When picture sharpness was the criterion, the grading appeared to depend on the *information per unit solid angle* conveyed to the observer's eye. For example, if two television pictures of the same height contain respectively 400 and 800 lines with appropriate bandwidths, their apparent sharpness is the same when the observers are twice as far away from the 400-line picture as from the 800-line picture.

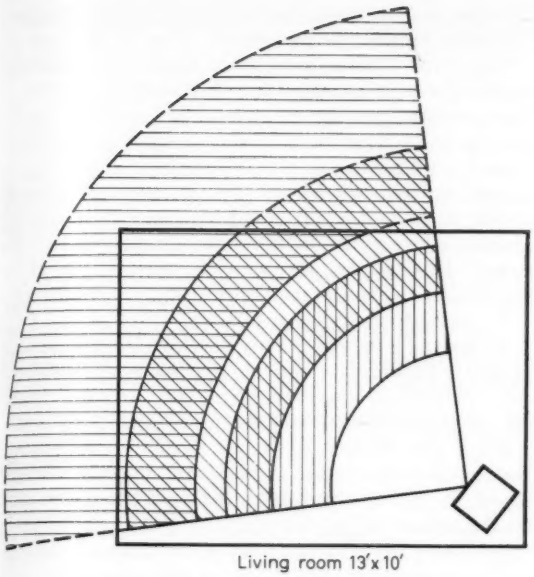
In the present series of experiments, an observer team was again used, but this time the individuals were left quite free to choose their own viewing conditions. The picture height and the chosen viewing distance were recorded. A number of optical projection systems were used on various screen sizes, and closed-circuit 405-line and 625-line television systems were investigated covering a range of video bandwidths. With the television systems some rather surprising results were obtained, which are apparently associated with the new experimental technique of allowing the observer to choose his own viewing distance to suit the picture quality and so make the most use of the information presented to him.

The optical experiments showed quite clearly that, with constant picture quality, the chosen viewing distance V was exactly proportional to picture height H, i.e. V/H = constant. If picture quality was reduced, the observers moved farther away, reducing the angle subtended by the picture at their eyes. At this lower standard, viewing distance was again proportional to picture height.

The results of the more important tests on the television systems are given in Fig. 1, which shows that the curves for the 405-line and 625-line systems with various bandwidths have a common tangent AB. The broken curve for the 819-line system has been calculated on the basis that it also shares this tangent. The unexpected feature of these curves is that the optimum video bandwidths for the 625- and 405-line systems, given by the points A and B, are about 2·5 and 1·25 Mc/s. The official channel allocations allow for 5 and 3 Mc/s respectively. The effect of deviating from the optimum is shown by comparing point C with A at the same bandwidth; since C is the point of intersection of the 819-line and 405-line curves, it is readily seen that an increase or decrease in the number of lines from the optimum of 625 results in an increase in V/H from



1 *Data obtained from viewing experiments*
s.w. = spot-wobble.
s.s.w. = synchronous spot-wobble.



2 *Viewing areas for various receivers*

The outline of a normal-sized living room shows that with 405 lines the optimum screen size is about 17 inches, and with 625 lines the optimum size is about 27 inches.

6·5 to 8·0, denoting a reduction in picture quality in both instances.

The two curves marked s.w. and s.s.w. are for a 405-line system with simple receiver spot-wobble (already shown to be an advantage) and a new type of scanning, synchronous spot-wobble, which permits the definition of the picture to be increased without increasing the number of lines. These show a progressive improvement in picture quality. For example, compare point D for synchronous spot-wobble with E for normal interlace at 7 Mc/s in Fig. 1. Theoretically the synchronous spot-wobble system should be capable of further improvement so that D eventually moves to F. A technique for obtaining the normal 2/1 interlace signal by sampling the synchronous spot-wobble system is described in the paper.

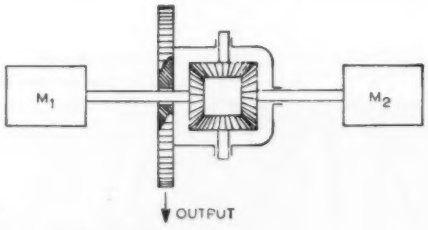
The practical implication of the results is shown in Fig. 2, which illustrates a typical domestic television installation. The three shaded zones are the preferred viewing areas for three different sizes of television receiver. The diagram shows, as has already been found commercially, that a 21-inch receiver with only 405 lines is too large for the normal living room. With 625 lines, however, a 27-inch receiver would be acceptable. There seems no doubt that new picture-reproducing techniques will make larger pictures possible by the time a colour-television system is established in Europe. The present results show that it is not uneconomical in bandwidth to provide a higher standard of definition, thus permitting these larger pictures to be used comfortably in the home. This higher standard could involve both an increase in the number of lines and the use of spot-wobble techniques.

621.397.5

Differential Locomotive Drive

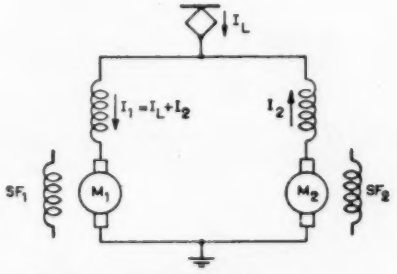
A short review of a Utilization Section paper (No. 2556) entitled 'The Principal Characteristics and General Analysis of a New Epicyclic Drive for Electric Locomotives', by H. E. J. Symes, M.Sc.(Eng.), Associate Member. The paper is published this month in Part A of the Proceedings. The author is with Adams, Symes and Partners, Johannesburg.

SMALL MINING ELECTRIC LOCOMOTIVES OF THE CONventional type with resistance-controlled series motors have a number of undesirable operational characteristics. In addition to these weaknesses, it is a common practice to employ semi-skilled personnel as drivers, and on many occasions locomotives are required to do work for which they were not designed. Consequently, during recent years, an investigation was made in South Africa to develop a simplified drive suitable for native labour and to improve service characteristics. Further important objectives were a reduction in maintenance costs and the



1 *Diagram of the drive*

M_1 and M_2 are the motors.



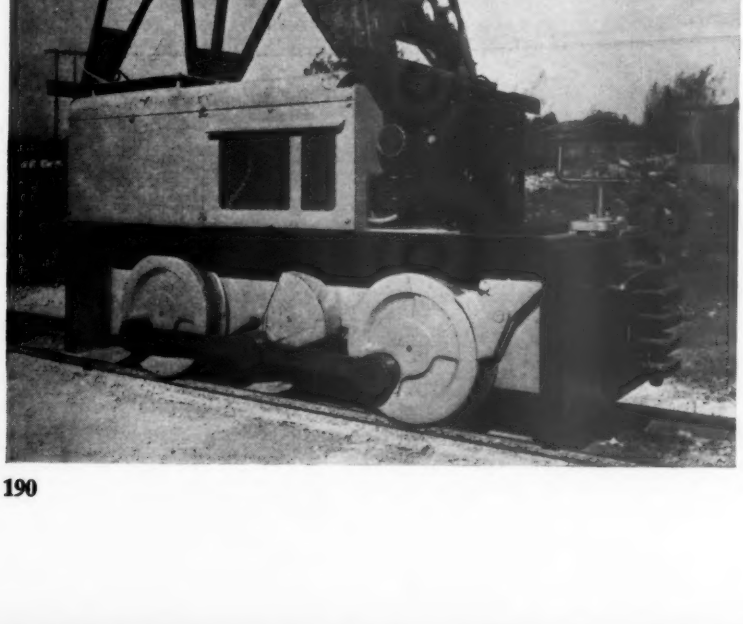
2 *Principal armature circuit*

I_L = locomotive line current.
I_1, I_2 = armature currents of motors M_1 and M_2.
SF_1, SF_2 = shunt-field windings of motors.

3 *Experimental locomotive*

4 *Prototype locomotive with temporary collector tower*

By courtesy of 'Coal and Base Minerals of Southern Africa'



incorporation of as many inherently safe and foolproof protective features as possible.

The drive eventually adopted used two compound-wound d.c. motors connected electrically in parallel and mechanically through a differential gear-box to the wheels. The arrangement, shown in Figs. 1 and 2, allows only the difference in motor speeds to appear at the output, so that the locomotive is stationary when the speeds of the motors are equal, and forward and reverse travel are determined by the motor running at the faster speed. During the locomotive's service period the machines are not stopped or reversed. Primary control is by manual shunt-field regulation.

Whenever tractive effort is developed while the locomotive is stationary or moving, the machines run of their own accord as a motor-generator pair, coupled through the planetary wheels, with the faster unit as the motor. There is then a circulating component of current around the closed armature loop. Neglecting machine and gear losses, the power drawn from the supply is always equal to the power at the wheels. The system is inherently regenerative for braking at any speed down to standstill, the faster machine then becoming the generator.

Briefly, the proved good features for a mining locomotive are as follows:

(1) The locomotive possesses the utmost simplicity and speed in handling, and a high degree of manoeuverability is obtainable.

(2) Whatever the shunt-controller setting, the circulating current in the series windings causes the locomotive to stall by equalizing the machine speeds before the motors are overloaded. At the stalling point the motors remain running and are well ventilated. For any load up to the maximum this feature permits automatic acceleration when the controller is set to full speed in a single step. Maximum tractive and braking efforts are always maintained within the limits of adhesion by the series windings.

(3) The starting current for any load and acceleration is small, and the locomotive draws a definite known maximum current from the supply.

(4) It is economical in power for slow-speed running; it can run continuously on any step of the controller.

(5) No heavy-current circuits are made or broken to control the locomotive; the light-field current controller does not arc or burn its contacts.

(6) Electric braking is used, eliminating brake wear, shoe dust, wheel flats, tyre wear, cracked or overheated tyres and fading. Braking effort can be applied and released almost instantaneously. A dead-man's handle is simple to incorporate by spring loading the controller to return to neutral.

(7) The drive is particularly suitable for such operations as loading and tipping cars, re-railing derailed vehicles, and holding or smoothly starting a load from rest on an incline.

(8) The required performance characteristic can be varied over a wide range, either in the design or on a completed locomotive.

(9) For inspection and maintenance the armatures can be rotated by hand without moving the locomotive.

(10) A separate ventilating blower is unnecessary. An efficient design of motor fan can be used because its rotation is always unidirectional.

Fig. 3 shows the experimental locomotive which was built for the investigation, the tests being carried out on a mine surface railway. It was made from components available at the time, the layout being arranged for photographic recording of the instrument readings, by using either a still or a ciné camera.

Fig. 4 is the prototype locomotive. The motors and gear-box are mounted on the deck plate under cover, the final drive being through jackshaft and side rods. The arrangement has the following advantages:

(1) For the same power and weight the locomotive can be built much shorter than the conventional design with axle-hung motors.

(2) For a given track gauge the width of the locomotive can be reduced by several inches and is limited only by the width over the crank pins.

(3) The unsprung weight is the minimum possible.

(4) Three-point suspension to improve running on rough track is simple to incorporate.

(5) The higher centre of gravity results in somewhat better riding and track-holding qualities.

(6) The axles cannot slip or skid independently when either motoring or braking. Total adhesion is independent of weight transfer arising from tractive or braking conditions.

(7) The maximum power of the locomotive is virtually independent of track gauge.

(8) Commutators and brush gear are easily inspected; pit facilities are not strictly necessary.

(9) All electrical components other than motors are in an easily removable box.

(10) The motors are less likely to be damaged by water and dirt.

621.337.1

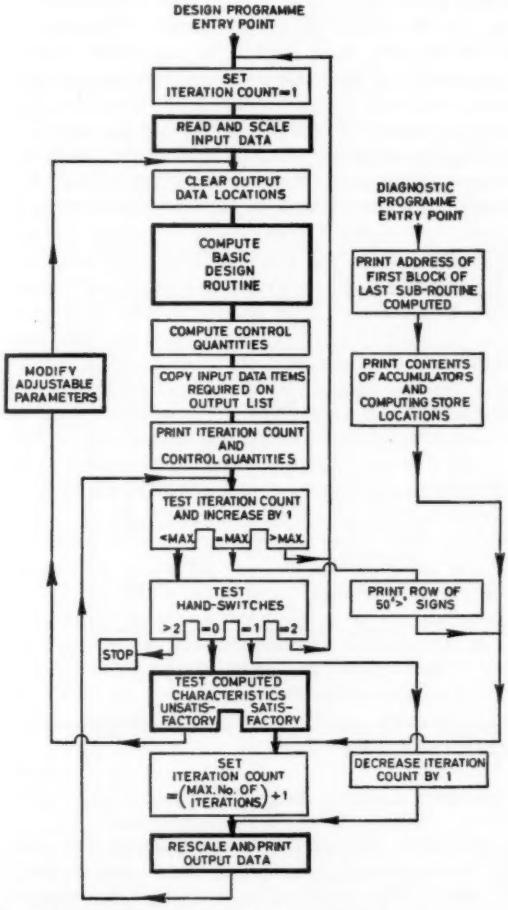
Digital Computer in Transformer Design

A short review of a Supply Section paper (No. 2404) entitled 'The Digital Computer Applied to the Design of Large Power Transformers', by W. A. Sharpley and J. V. Oldfield, B.Sc.(Eng.), Graduate. The paper was published individually in August 1957, and it is republished this month in Part A of the Proceedings. Mr. Sharpley is with Bruce Peebles and Co., and Mr. Oldfield is at Queen Mary College, University of London.

THE ADVENT OF THE HIGH-SPEED ELECTRONIC DIGITAL computer has made possible considerable savings of time and effort in the numerical solution of mathematical problems. Attention has been paid recently to its use in transformer design, a process of considerable logical complexity. The digital computer is a powerful tool for problems of this type since it contains discriminatory as well as arithmetic faculties. A preliminary survey of the application of a computer to the design of rural-type transformers was given in an earlier paper.*

The design process has been divided into short sections, which, when programmed, are called sub-routines. The divisions have been made for convenience in programming and also to make the best use of the facilities provided by the high-speed store of the Pegasus computer. Selected sub-routines are discussed in detail in the paper, and the method developed to control the order of computation through the sub-routines is also described.

The complete sequence of operations in the programme



1 *Flow diagram for computer programme*

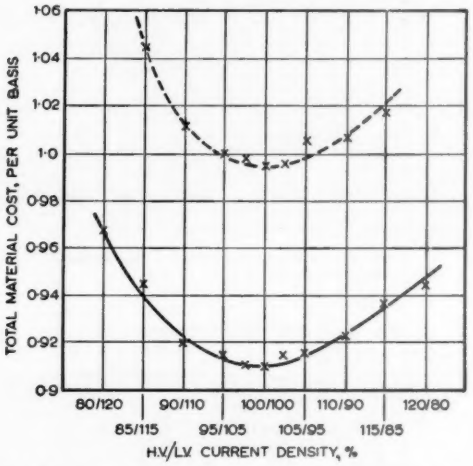
is shown as a flow diagram in Fig. 1, and it will be seen that provision is made for automatic modification of certain starting quantities (flux density, winding current densities and core diameter) to cause the design to converge to satisfactory characteristics (iron loss, load loss and reactance). This forms an important part of the

* OLDFIELD, J. V., McDONALD, D., and HUMPHREY DAVIES, M. W.: 'Transformer Design with Digital Computers', *Proceedings I.E.E.*, Paper No. 2159 M, September 1956 (103 B, Supplement No. 1, p. 54).

programme. The scheme is based on approximate relationships between design parameters and characteristics, e.g. between flux density and iron loss. It has been tested rigorously by specifying starting quantities 20% removed from those which were known to be required. The designs converged rapidly to within $\pm 1\%$ of the specified characteristics.

Both the data given to the computer before commencing a design and the results received from it are in the forms normally used in design. The conversion of data is carried out by input and output scaling routines, which ensure that any number x used in the computer lies within the range $-1 \leqslant x < 1$; this requirement is imposed by the design of the computer. Although the results are accurate to at least seven significant figures, they are printed to four only, giving sufficient accuracy for design purposes and economizing in computer time.

The programme is at present applicable to a range of high-voltage transformer designs from 30 to 210 MVA and is being extended to cover a wider range. The designs computed have been found at least as satisfactory as

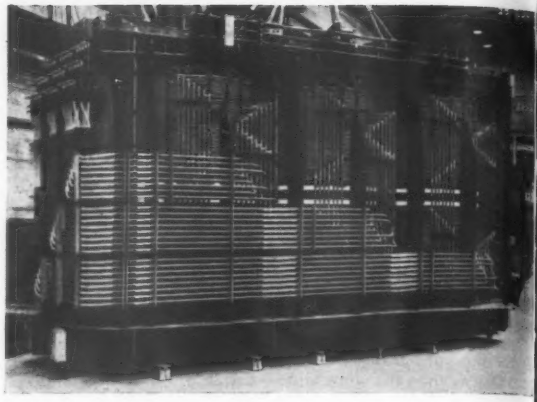


2 *Variation of material cost with current-density ratio: 72 MVA transformer*

those produced by hand. The programme has been applied to routine design work and also to special design investigations. The results of a study to determine the influence on cost of the ratio between the high- and low-voltage winding current densities of a 72 MVA transformer are given in Fig. 2. A view of this transformer is shown in Fig. 3. An analysis is given of the time taken in another investigation, in which seven complete designs, all meeting the desired characteristics to within $\pm 2\%$, were produced in approximately 17 minutes.

The application of a computer to transformer design permits rigorous analytic solutions of the numerous associated problems to be used during routine calculation, which, by hand, would require an uneconomical amount of time.

621.314.2 : 621.374.32 : 681.14

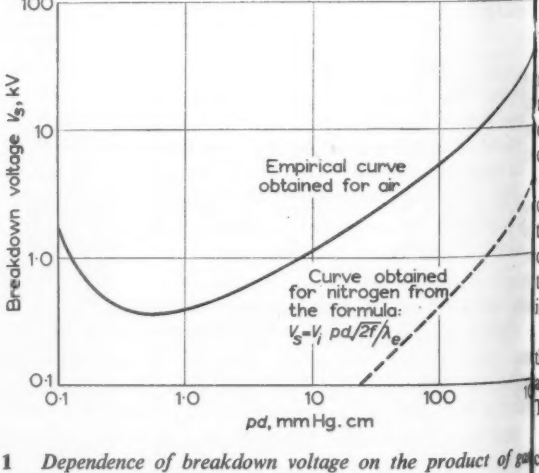


3 *View of 72 MVA transformer*

Electric Breakdown in Gases

A short review of a Graduate and Student Section paper with the above title by A. E. D. Heylen, B.Sc.(Eng.), Ph.D., Student. The paper was read before the London Graduate and Student Section on the 3rd April 1957, and it was awarded a Graduate and Student Premium by the Council. The author is at Queen Mary College, University of London.

PROGRESS IN THE UNDERSTANDING OF BREAKDOWN phenomena has come largely through the study of discharges between parallel plates suitably rounded at the edge and separated by a gap of a few millimetres. When a voltage V, applied to such a uniform field gap, is



1 *Dependence of breakdown voltage on the product of gas pressure and gap distance (Paschen's law)*

increased to the threshold voltage V_s, a spark occurs. As early as 1889 it was observed that at constant temperature this voltage is a function of the product of the gap distance d and the gas pressure p. This is known as Paschen's law. A V_s/pd curve for air is shown by the solid line in Fig. 1, and the form is typical of all other gases. This curve has obvious engineering importance but sheds little light on the mechanism of breakdown itself.

The pre-breakdown processes are vital, and it was to obtain information on these that Townsend (in 1900) began to make conductivity measurements in gases. A typical current/voltage curve is shown in Fig. 2. This

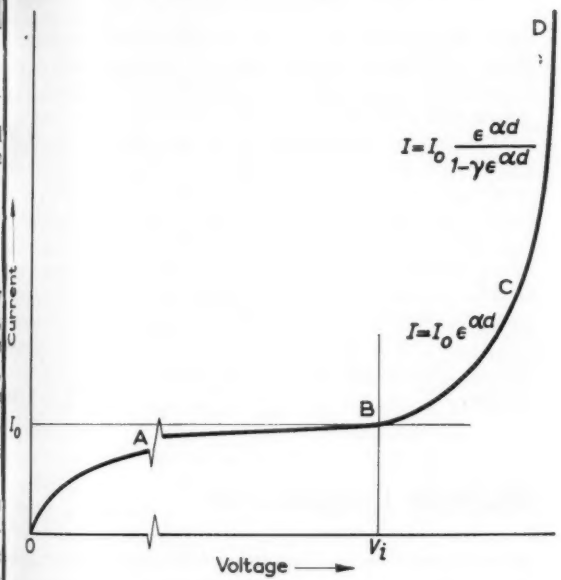


Fig. 2. Relationship between the current through a gap and the voltage across it

relation can be examined quantitatively and qualitatively; with the latter approach, a clear physical picture of what is actually happening in the gap up to breakdown can be obtained.

If electrons are introduced (by natural radiation or otherwise) into a gap between electrodes in an ideal gas, they will acquire, by elastic collision, the mean energy of agitation of the atoms, which is 0·025 eV at room temperature. The fractional energy exchange f on elastic impact is small and of the order of 10^{-2}.

When an increasing field is applied across the gap, the electrons drift in the general direction of the field, and most of them are merely collected at the anode. This corresponds to the region OA of Fig. 2.

Over the wide range AB, the mean electron energy is continuously increased until, at B, some of the electrons crossing the gap have acquired an energy greater than the ionization potential V_i, which for nitrogen is 15·5 eV. Electron multiplication by ionization then sets in.

By equating the energy gained by the electrons in moving in the direction of the applied field to the energy lost by them in elastic collisions with gas atoms, the average electron equilibrium energy U can be derived as:

$$U = \frac{\lambda_e}{\sqrt{2f}} \cdot \frac{E}{p} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where E = field strength (V/d) in volts/cm, and λ_e is the mean free path of the electrons in centimetres. Postulating that for breakdown to occur, $U = V_i$:

$$V_s = V_i \cdot \frac{pd\sqrt{2f}}{\lambda_e} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Eqn. (3), for nitrogen, is represented by the broken line in Fig. 1.

In practice, atoms do not behave in this ideal fashion but show up their fine structure. When a collision occurs between an atom and a free electron with energy less than the ionization energy, one of the orbital electrons may be ejected to a next higher orbit. The collision is then said to be inelastic, and the atom is in an excited state. The energy transfer involved in this process is much larger than that expended in elastic collisions, but less than that used in ionizing collisions where complete ejection takes place. Thus, inelastic collisions present a real barrier to the easy accumulation of energy by the electrons moving in the gas under the influence of the applied field, and much higher values of E/p are required for the electrons to make ionizing impacts.

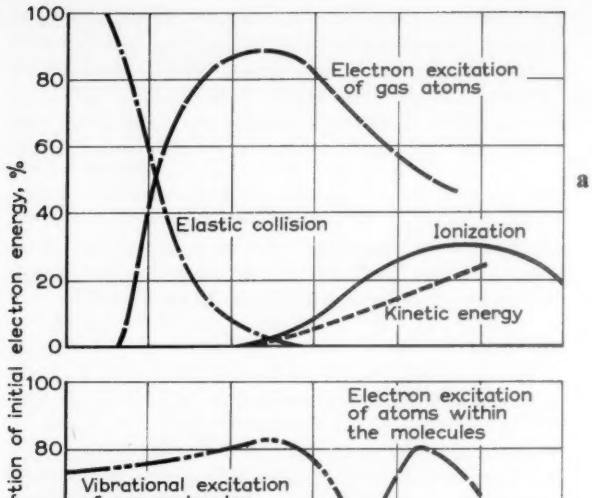
When molecules rather than atoms constitute the gas under test, the inelastic collision barrier due to electron excitation is preceded by one due to rotational and vibrational excitation, i.e. energy is given up by the colliding electron to increase the movement between the various atoms, which may rotate or vibrate relative to one another inside the molecule. The energy exchange involved in this type of inelastic collision falls between that of elastic collision and inelastic electron excitation, but the number of levels may be large. The inelastic losses as a whole account for the discrepancy between the two curves of Fig. 1.

The fundamental picture of collision processes preceding gaseous breakdown is well illustrated by the curves of Fig. 3. The fraction of the total energy of the electrons (received from the electric field) spent in the various collision processes is shown plotted against E/p [or, by eqn. (1), against electron energy U]. For hydrogen, the electron excitation barrier is preceded by a vibrational one, which is absent for the monatomic gas neon.

Quantifying the ionization process of the gas by electrons, Townsend defined α, now called Townsend's first ionization coefficient, as the number of ionizing collisions made by one electron in moving 1 cm in the direction of the field, and he showed that:

$$I = I_0 \epsilon^{\alpha d} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where $\epsilon^{\alpha d}$ can be regarded as an amplification factor.



3 *Proportion of initial electron energy expended in various gap processes, plotted against a function of the initial energy*

a Neon. **b** Hydrogen. Note that with neon, a monatomic gas, there is no absorption of electron energy in vibrational excitation of molecules, as there is with hydrogen.

This is borne out by experiment, as shown in region BC of Fig. 2. It was found that α/p is uniquely dependent on E/p, and, using the above simplifying assumptions, Townsend was able to account for the variation by the relation:

$$\frac{\alpha}{p} = A\varepsilon^{-\frac{B}{E/p}} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

From more detailed considerations of the picture presented, it can be shown that:

$$B \sim V_i \times \text{elastic loss} \times \text{inelastic loss}$$
$$A \sim \text{elastic loss}/(V_i \times \text{inelastic loss})$$

The larger the ionization potential and the inelastic losses, the smaller will α be.

To account for the faster-than-exponential current increase in the range CD (Fig. 2), Townsend invoked a second coefficient γ to represent the secondary mechanisms that can take place, and he derived an expression for the current reaching the anode:

$$I \simeq I_0 \frac{\varepsilon^{\alpha d}}{1 - \gamma\varepsilon^{\alpha d}} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Eqn. (5) is typical of formulae describing potentially unstable systems, such as the action of feedback amplifiers or the operation of nuclear reactors. It exhibits gain $\varepsilon^{\alpha d}$ and feedback γ; the suitable combination of the two leading to breakdown. Thus a spark will occur if the reproduction constant $\gamma\varepsilon^{\alpha d}$ is greater than or equal to unity:

i.e. $$\gamma\varepsilon^{\alpha d} \geq 1 \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

A simple and accurate formula for breakdown can be obtained by the substitution of eqn. (4) into the breakdown criterion of eqn. (6). This yields:

$$V_s = \frac{Bpd}{\ln(pd) + \ln(A/\ln\gamma^{-1})} \quad . \quad . \quad . \quad (7)$$

From this formula it is clear that the larger the quantity B and the smaller the quantity A, the larger will be the breakdown voltage for a particular value of pd. This means that the larger the ionization potential and the inelastic losses, the higher will be the value of V_s, which agrees with previous considerations. Eqn. (7) yields the empirical curve of Fig. 1. In practice, however, it is found that these two requirements for a high-electric-strength gas do not go together. In a complex gas, the losses incurred by electrons in inelastic collisions are larger, but the ionization potential is lower. However, since the electric strength increases with molecular complexity, it can be concluded that the strength of gases is mainly determined by the size of the inelastic-collision barrier.

621.3.015.5 : 621.315.61

Analogue Computation

A short review of a Graduate and Student Section paper entitled 'Some Aspects of Analogue Computation', by J. C. Earls, B.Sc.(Eng.), Graduate. The paper was read before the North Scotland Graduate and Student Section on the 22nd February 1957, and it was awarded a Graduate and Student Premium by the Council. The author is at Robert Gordon's Technical College, Aberdeen.

EVER SINCE THE INTRODUCTION OF ARITHMETICAL METHODS attempts have been made to simplify the process of calculation. Examples of successful methods for reducing the labour of calculations are the abacus and logarithmic tables.

Owing to the increasing complexity of problems which arise in engineering, science and commerce, further development of calculating machines has been necessary. Most recently, electro-mechanical and electronic computers have been produced which simplify considerably the analysis of contemporary mathematical problems. These computers can perform the ordinary arithmetical operations of addition, subtraction, multiplication and division and can be used for the solution of a variety of problems in applied mathematics.

In analogue computers magnitudes are represented by various values of a single physical quantity, such as voltage. Operations are performed by the computer on these quantities, and the solution is given by another physical quantity which can be interpreted as a magnitude. A slide rule is an example of an analogue computer, where the logarithms of the components of the calculation are represented by lengths on the rule. The result of the slide-rule operation is another length which is the logarithm of the answer.

There are many types of analogue computer, and their applications are numerous. They may be classified according to the physical quantities which are used to represent the mathematical variables and according to the computing elements—mechanical, electro-mechanical and electrical.

In this review attention will be confined to some aspects of d.c. electronic analogue machines, which use direct voltages varying with time, to represent the mathematical variables. Time is usually used as the independent variable in the solution of differential equations.

The accuracy of analogue computers depends largely on the accuracy and stability of the components of the computing elements. An accuracy of $\pm 1\%$ is good and an accuracy of $\pm 5\%$ is average. However, great accuracy is not always required, since the accuracy of the input variables may not be very high.

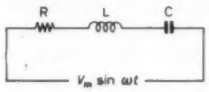
The main advantage of the analogue over the digital computer is that it is generally a model of the actual system under consideration, and if the computer solves the problem at the same speed as the actual simulated system operates, then actual parts of the practical system may be included in the computer arrangement. This may be particularly useful if a component of the working system is difficult to simulate. Under these circumstances the computer is said to work on a *real* time scale. It is possible either to slow down or to speed up the solution of, say, the response of a dynamical system. This aspect of d.c. electronic analogue computation will be referred to later.

D.C. electronic analogue computers are very useful for solving problems involving differential equations. Typical applications are the analysis of the flight of a guided missile, the response of an automobile suspension to road surface changes and an analysis of the response of servo systems in automatic-control processes.

There are basically two main types of analogue computer—differential analysers and simulators.

The differential analyser is used for solving the differential equations appropriate to a dynamical system. It is often of the repetitive type—a disturbing function is repeatedly applied to the analogue of the system and the response is obtained repetitively at a frequency of the order 10–60c/s. Thus the response can be displayed on a cathode-ray oscilloscope. The parameters of the system can be varied and the change in response observed. An example of this type of repetitive solution might be the response of a servo system to a step-function disturbance.

As a further example consider the electrical circuit shown in Fig. 1. Here an inductance L, capacitance C, and resistance R are connected in series across a sinusoidal voltage supply.



1 *Series circuit with sinusoidal disturbance*

If the above system is analysed the following differential equation is obtained:

$$L\frac{d^2i}{dt^2} + R\frac{di}{dt} + \frac{1}{C}i = \omega V_m \cos \omega t$$

where i is the circuit current.

If $L = 1\,\text{mH}$ and $C = 100\,\text{pF}$, the natural resonant frequency of the above circuit is approximately 10^6c/s, and since the response of the system will be required at or near the resonant frequency the disturbance frequency will be about 10^6c/s. The above differential equation may be solved, that is, the response of the circuit determined, by using a d.c. electronic analogue computer. However, frequencies of the order of 10^6c/s cannot be handled by the components of a d.c. analogue computer, and the solution of the problem has to be slowed down by a factor of approximately 10^6. The disturbing function would then have a frequency of about 1c/s, and the coefficients of the equation would have to be correspondingly adjusted.

Thus, in the above problem the disturbing function as applied to the differential analyser is a sinusoidal voltage with a frequency of about 1c/s. There is no need to use a d.c. electronic analogue computer for the solution of such a simple problem as the above. However, if the disturbing voltage is not easily analysed in mathematical terms, a differential analyser might be used with advantage.

When an analogue computer is used as a simulator it works on the real time scale, and actual working parts of the dynamical system under consideration may be included in the computer. An analogue machine of this type is as much a model of the system under study as a mathematical calculating machine.

There is little difference in principle between the above types of analogue computer. For any particular system the type of computer used would depend upon the approach to the problem. Mathematicians would probably favour the differential analyser, engineers—who are more interested in the working of the dynamical system and its components—would probably use a simulator.

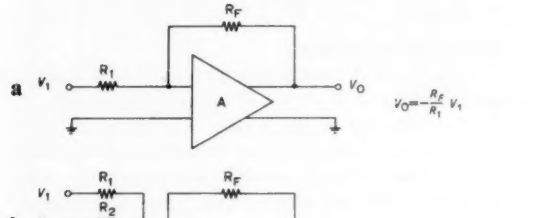
The solution of a problem by means of a d.c. electronic analogue computer generally depends upon the use of the following operations:

(*a*) Addition of two or more variables together.
(*b*) Multiplication of a variable by a positive or a negative coefficient.

(c) Multiplication of two variables.
(d) Generation of functions of variables.
(e) Time integration of a variable.

The principal element in a d.c. analogue computer is the high-gain d.c. amplifier. The gain of d.c. amplifiers used in computing circuits should be preferably infinite, as will be seen later. Gains of the order of 10000 and higher are normally satisfactory. The input impedance to the amplifier is regarded as infinite and the output impedance zero. Further, the amplifier should be able to handle frequencies in excess of the highest input-signal frequency.

If d.c. amplifiers satisfying the requirements indicated above are connected in the circuits shown in Fig. 2, the



2 *Circuit elements in common use*
a Multiplication circuit. **b** Addition circuit. **c** Integration circuit.

input and output circuit voltages will be related to each other by the expressions quoted.

The quantities V_1 and V_0 are the circuit input and output voltages respectively. The magnitude of the gain of the d.c. amplifier is A, but there is also a 180° phase shift between the amplifier input and output terminals.

The circuit of Fig. 2*a* is used for the multiplication of a variable by a constant coefficient. R_1 is the input resistance, R_F is the feedback resistance.

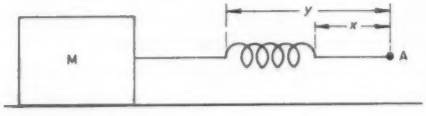
To add two or more variables together the circuit of Fig. 2*b* is used. V_1, V_2 and V_3 are three input voltages fed into the input of the amplifier via the input resistances R_1, R_2 and R_3. From the expression relating the input and output voltages, it can be seen that various proportions of the input voltages may be added together. However, if $R_1 = R_2 = R_3 = R_F$, the output voltage is equal in magnitude to the sum of the three input voltages.

Fig. 2*c* indicates the circuit for the integration of a variable with respect to time. If the output voltage is required to have an initial value, this may be incorporated as an additional feature of the integrator circuit.

By the use of the above basic circuits, ordinary linear differential equations with constant coefficients may be solved. Equations of this type can be solved easily by analytical methods. However, a simple computer can solve problems of this type with the additional advantage that the disturbing function and the coefficients can be altered quickly and the solution obtained. Computer circuits to perform time differentiation of a variable are seldom used. They tend to be unstable and also degrade the signal/noise ratio. Whereas, in theory, ideal integration is possible, an ideal differentiator is impossible to obtain.

Differential Analyser and Simulator Approach to a Simple Dynamical System

A simple dynamical system is indicated in Fig. 3. A mass M rests on a surface, the coefficient of friction of which is μ. The mass is attached through a rigid coupling



3 *Simple dynamical system*

to a spring of stiffness k. The positions of the spring in the unstressed position measured from A are x and y. If x is varied by the application of an external force at A, a tension T will appear in the spring, and y will vary, its motion being determined by the constants of the dynamical system: μ, M and k. An analogue computer can be used to obtain the value of y, for any variation in x.

The equations of the dynamical system of Fig. 3 are:

$$T = k(x - y) \quad . \quad . \quad . \quad . \quad (1)$$

$$M\frac{d^2y}{dt^2} = T - \mu M\frac{dy}{dt} \quad . \quad . \quad . \quad (2)$$

If only y is required, T can be eliminated from eqns. (1) and (2) thus:

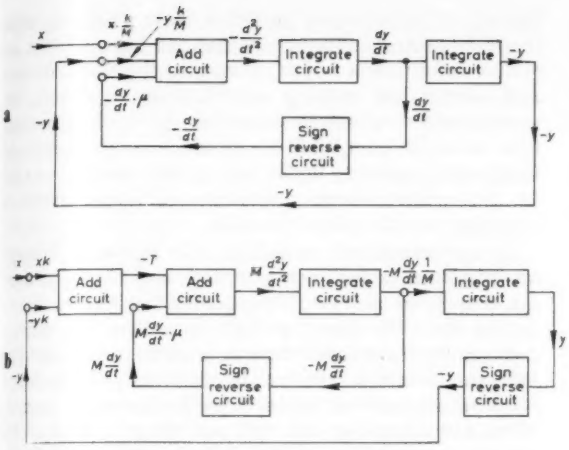
$$M\frac{d^2y}{dt^2} = k(x - y) - \mu M\frac{dy}{dt}$$

or

$$\frac{d^2y}{dt^2} + \mu\frac{dy}{dt} + \frac{k}{M}y = \frac{k}{M}x \quad . \quad . \quad . \quad . \quad (3)$$

A differential analyser which may be used to solve the above second-order differential equation is shown in Fig. 4*a*. The input disturbing function x could be made periodic, thus making the computer repetitive, and the response y could be displayed on a cathode-ray oscillograph.

If the dynamical system of Fig. 3 is to be simulated by an analogue computer, the tension T would not be eliminated, and eqns. (1) and (2) would be solved simultaneously. The circuit of a simulator which is an analogue model of the dynamical system is shown in Fig. 4*b*. By means of the simulator the tension in the spring and the



4 *Circuits for the elucidation of the dynamical system*
a Differential analyser. b Simulator.
The open circles represent multiplication by a constant coefficient.

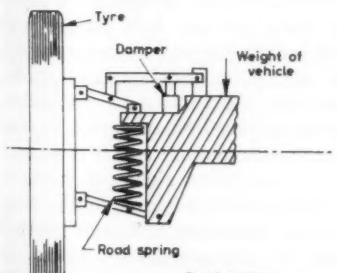
frictional force can be measured. Thus, a more direct comparison with the actual dynamical system is obtained.

Dynamical Systems with Non-Linearities

In the preceding examples the solution to linear differential equations with constant coefficients were obtained. However, such problems can usually be solved easily by analytical methods—except when the disturbing function is an arbitrary function of time.

For systems with non-linear functions, variable coefficients, or high-order derivatives, the solution is more easily obtained by the use of analogue computers.

Consider the typical suspension system of a road vehicle shown in Fig. 5.



5 *Road vehicle suspension*

An analogue computer to simulate the above physical system could be built, the input to the computer being the variations in road level measured from some mean position, and the principal output from the computer being the height of the corner of the vehicle from some datum. If continuous variations of road level are applied the parameters of the system can be varied—e.g. damping, spring stiffness, tyre pressure, etc., and the resultant variation in vehicle behaviour observed.

Typical Non-linear Elements in a D.C. Electronic Analogue Computer

A multiplier is a non-linear element and should be capable of forming the product of two variables which may be positive or negative depending on the sign of the variables. Such a multiplier is termed *four-quadrant*. Where only one of the variables can alter sign during the computation, the multiplication is said to be *two-quadrant*. *One-quadrant* multiplication implies that both variables are constant in sign during the computation.

It has already been indicated that in the process of solving dynamical problems by analogue methods it is necessary to generate a function of a variable. Function generators are generally non-linear elements, and the function may be algebraic, trigonometric or completely arbitrary. An instance of the use of an arbitrary function was given in the problem of vehicle suspension, whilst trigonometric-function generation might be required, for example, in a ballistics problem.

Summary

Analogue computation methods are used in many diverse fields of engineering and science and are particularly useful since they form a working model of the system under consideration. Versatile multi-purpose computers have been built, which, by the use of patch panels serving to interconnect the computing elements, can help to solve problems in automatic control, atomic energy, aircraft design and many other branches of engineering and science.

621.317.79 : 681.142

Television Film Recording

A short review of a Graduate and Student Section paper with the above title, by E. J. Stocks, B.Sc.(Eng.), Graduate. The paper was read before the London Graduate and Student Section on the 21st January 1957, and it was awarded a Graduate and Student Premium by the Council. The author is with Independent Television for Wales and the West Ltd.

FILM RECORDINGS OF TELEVISION TRANSMISSIONS ARE OF great value for 'post-mortem' examinations of programmes by technicians and performers, for the preservation of historic events and as an economical means of repeating transmissions. The process of tele-recording also finds application where it is desirable or necessary to film a programme in advance, because advantage can then be taken of the speed and continuity of television production techniques. By arranging that the resultant films conform substantially to the accepted dimensional and speed standards, full use can be made of the processing, editing and viewing facilities which already exist in the film industry.

The cinematograph projector creates the illusion of continuous movement by displaying a rapid sequence of still photographs. The film is moved one frame at a time by an intermittent mechanism in both camera and projector. In normal cameras the shift period is one-half of the frame repetition period, while the usual 35 mm projector mechanism will move the film in one quarter of the repetition period. In cinematograph engineering it is often convenient to refer to the picture repetition period as 360° of rotation, so that the camera and projector shift periods referred to above then become 180° and 90° respectively. The standard repetition rate for sound films is 24 frames per second.

In television, where all information has to be conveyed over a single channel, analysis must be carried a stage further, and so the image to be transmitted is scanned or read like a book. The eye then integrates the elemental scanning spot into a complete picture, the scanning process taking place at the rate of 25 whole pictures per second. To reduce flicker, the technique of interlace is adopted, i.e. alternate lines of a complete picture are transmitted as one field and the remaining lines then sent as a second field, so that, although the eye is virtually presented with 50 pictures per second and is thus unconscious of flicker, the information transmitted corresponds to 25 complete images only. Between successive lines and between successive fields of the scanning operation, brief intervals of time are allowed for the scanning beams to return to their respective starting-points, and no picture information is transmitted during these intervals. The inter-field period of the British television system is equivalent to only $12\frac{1}{2}°$, which is an impossibly short shift period for 35 mm film, so that a basic difficulty is to record a complete picture while allowing for practical speeds of film movement.

To avoid interference patterns between the line structures of the recorded and transmitted images when a tele-recording is rescanned, it is necessary to eliminate the lines of the filmed picture. This is achieved by the well-known technique of spot-wobble in which a high-frequency vertical oscillation is applied to the electron beam in the recording cathode-ray tube of such an amplitude that each line just meets and blends into the next. Tonal distortions are reduced by passing the electrical video signal through non-linear circuits, which can be adjusted to compensate for the characteristics of the various links in the recording and reproducing chain, viz., recording cathode-ray tube, negative film, positive film and tele-cine scanner. Settings are made with the aid of an electronically generated step wedge, which acts as a standard invariable picture subject covering the whole tone range. It appears on the picture tube as a series of ten vertical bars graded in tone from black to white, the individual brightnesses of which can be measured with a photo-electric meter.

A certain type of cinema projector can be adapted to produce images of a television picture on successive frames of a continuously moving film, and has been extensively used for the production of tele-recordings. There is no obscuration period in these machines, each frame dissolving continuously into the next, so that no picture information is lost. Owing to the fact that film and images are moving continuously, however, the unavoidable mechanical tolerances in mechanism and film make it impossible to produce a photographed image with complete uniformity of line spacing, so that an undesirably large amplitude of spot-wobble is necessary to reduce line structure.

In *suppressed-field* recording, only alternate fields of an interlaced picture are recorded, and those between are suppressed, so that the recording film can be moved during the $192\frac{1}{2}°$ blank periods by a slow intermittent mechanism of orthodox design. Despite the rejection of half the available picture information, results upon retransmission are surprisingly good, although a stepped effect can sometimes be seen on oblique lines of the subject-matter owing to the coarser structure of the recorded image. The acceptability of the system is probably due to the subjective interpretation of the picture by the brain, which, seeing a complete set of lines in the reproduced image, subconsciously assumes that the vertical definition corresponds to this, whereas it really corresponds to only a half-set of lines.

A system known as *afterglow recording* is an extension of the suppressed-field technique. It relies upon tube afterglow to retain picture information received during the film-shift period and to apply it to the next frame of film. However, analysis of conditions for various lines on the film frame indicates that with a normal picture displayed on the recording tube there would be a considerable variation in effective exposure. The decay characteristic for phosphor afterglow is roughly exponential; thus, lines traced on the tube immediately after the film has come to rest will receive the benefit of the bright initial part of the decay curve, while those traced as the film begins to move will not be applied to the film until the latter comes to rest one half picture period later, and their effective exposure will be due only to the decayed tail of the afterglow curve. Examination of intermediate lines between these two extremes indicates a top-to-bottom exposure variation of about 5 : 1 over both fields of each complete picture, and it is necessary to amplitude-modulate the video signal at frame frequency in order to ensure that all lines of the picture receive the same effective exposure. Sufficient brightness must be kept in hand for the modulation process, and consequently slower film stocks cannot be used, while, owing to the afterglow, any one frame of film will contain components of three successive television fields, so that smearing is noticeable upon rapid movement. Although the mass of 35 mm film prevents its being moved within the television inter-field period, it is possible to construct an intermittent mechanism which will move the film in a period of about $2\frac{1}{2}$ times the inter-field value. It is practicable to use such a camera with a short-afterglow recording tube, when the 38 lines obscured by film shift will be lost, or with a long-afterglow tube for recording full information, when the brightness modulation

required is only 1·3 : 1. Thus, with the latter, slower films can be used than in the afterglow system described above.

The smaller mass and linear speed of 16 mm film have made possible the construction of an intermittent mechanism to move the film within the duration of the television inter-frame period. With ultra-fine-grain film, results are as good as the best 35 mm recordings.

An alternative approach to the subject may be adopted. When it is desired to pre-film a programme by telerecording, as opposed to the recording of a live transmission, there are advantages to be gained by using a non-standard television system, expressly evolved to facilitate the recording process. For example, in the recording of a normal interlaced picture to give full information, any one frame of film will be composed of two fields of scan, so that any moving object will appear as a double image. This can be avoided by employing sequential scanning, in which each television field produces one film frame. By specifying an inter-field period slightly greater than that required for film shift (35° would be a suitable value in conjunction with the accelerated 35 mm mechanism mentioned above) problems of information loss are avoided. The extra inter-field time thus made available can be used to inject into the video system an electronic step wedge, which will appear on all picture and waveform monitors and thereby provide an invaluable set of reference tones for setting up and matching the electronic cameras and monitors, as well as giving a continuous check upon the tone corrections applied in the recording channels. A studio equipped on these lines has been operated for about two years, and the system has been found quick and reliable for the production of certain types of television film. 621.397.5

SYNOPSES OF PAPERS

The following are synopses of papers published in the *Proceedings* which have not been read at an Institution meeting and which have not been described under 'Short Reviews of Papers'. They are included here primarily for reference. The papers have not been published individually, as have those for reading at meetings, but reprints of them will be available shortly (see p. 204).

Losses in Pump Induction Motors

A synopsis of a Utilization Section paper (No. 2525) entitled 'Eddy Currents and Wall Losses in Screened-Rotor Induction Motors', by R. L. Russell, M.Sc., Associate Member, and K. H. Norsworthy, B.Sc., Graduate. The paper is published this month in Part A of the Proceedings. The authors are at the University of Bristol.

THE PROBLEM OF CIRCULATING CORROSIVE LIQUIDS assumes major importance in nuclear-engineering practice, where the standards of safety and reliability which are imposed demand sealed circulating systems. One method employs a completely enclosed centrifugal pump driven by a squirrel-cage induction motor in which the rotor is separated from the stator by a thin cylindrical corrosion-resistant shell, which is situated in the air-gap of the machine and effectively forms part of the retaining wall of the circulating system. A precise assessment for design or development purposes depends on a knowledge of the power losses in the stationary shell, and it is a solution of this eddy-current problem which is developed in this paper.

Arguments more appropriate to field theory than to circuit theory lead to a classical boundary-value problem which takes into account the nature and thickness of the shell and the length of overhang, and provides formulae for current densities, flow lines and dissipated power in terms of ordinary machine parameters and the dimensions and electrical constants of the shell. Theoretical and practical results are compared and shown to be in close agreement. Some of the graphical results display a pronounced slot effect and suggest methods for making a more detailed investigation.

The theory can be extended to correspond to a composite shell of complex structure, and it has some bearing on the principles employed in drag-cup motors, to which it could be applied. 621.313.333

Current Gain of Transistors

A synopsis of a Radio and Telecommunication Section paper (No. 2548) entitled 'An Investigation of the Current Gain of Transistors at Frequencies up to 105 Mc/s', by F. J. Hyde, M.Sc., Associate Member, and R. W. Smith, B.Sc. The paper will be published in Part B of the Proceedings. The authors are at the Radio Research Station.

APPARATUS IS DESCRIBED BY MEANS OF WHICH THE SHORT-circuit current gain is measured directly. Results of such measurements are presented for commercial alloy-junction and surface-barrier transistors; corrections are applied to yield the internal diffusion-current gain. The effects of stray capacitances on the measurements are discussed. The cut-off frequency of the internal current gain is compared with values derived indirectly from other measurements. For alloy-junction transistors the behaviour is closely in accord with existing one-dimensional diffusion theory, with some reservations, but for surface-barrier transistors the agreement is less close. 621.382 : 621.317.79

OBITUARY

GEORGE AUTERSON

George Auterson, B.SC., died on the 18th January 1958, when what promised to be a highly successful career as Principal Electrical Engineer Surveyor to Lloyd's Register of Shipping was cut short with tragic suddenness by a road accident. Returning from the house of a friend, where he had spent the afternoon watching on television the England *v.* Wales rugby match at Twickenham, his car was struck at an uncontrolled crossing with this fatal result. It is a sad reflection that this journey, which ended so tragically, would have taken a mere five minutes if completed safely.

Auterson was born at Newry, Northern Ireland, on the 12th September 1911 and, after attending two schools in Newry, spent three years studying at Queen's University, Belfast. He graduated as a B.Sc. with 1st Class Honours in 1932. He completed a two-year graduate apprenticeship with the Metropolitan-Vickers Electrical Co. at Trafford Park, and later spent time in the Standards Laboratory, the Meter Department, and the Marine Department of the firm.

He always had a decided leaning towards marine interests, and while at Belfast he frequently availed himself of opportunities to study shipyard practice. This interest also extended to yachts, with whose construction he was well acquainted.

When he joined Lloyd's Register of Shipping in 1936, as an Electrical Engineer Surveyor, he was therefore obeying a natural bent and undertaking a career which he could follow with enthusiasm. For the next ten years he was stationed at Sunderland and was responsible for survey of the electrical equipment of ships, including auxiliary naval craft, under construction over the whole of the North-East Coast. His practical advice and tactful approach undoubtedly influenced local standards and methods and earned for him universal respect and popularity.

In 1946 he transferred to London headquarters, where he had even greater opportunity to influence trends and new developments as Senior Electrical Engineer Surveyor. His advice was freely sought and appreciated by shipowners and shipbuilders. In 1956 he succeeded to the post of Principal Electrical Engineer Surveyor. His duties involved visits to the Continent, where he invariably established lasting connections with leading shipping officials in various countries.

The Institution's Committee on Regulations for the Electrical Equipment of Ships have recently been very actively engaged on a revised edition of the Regulations, and in the Committee's deliberations Auterson was taking a leading part. He was also active on various B.S.I. committees concerned with marine standards, such as those recently published on cables and motors and generators. He was Chairman of an I.E.C. sub-committee dealing with overload and short-circuit protection.

His outside interests centred on his home life and on the education of his two sons. While moderate in all things, he derived with characteristic zest a keen pleasure, when opportunity presented, in the good things of life—good fellowship, classical music, dancing, good food and wine. As a colleague and a friend he was intensely loyal, and his cheerful companionship was a constant stimulus to all who knew him.

George Auterson joined The Institution as an Associate Member in 1943 and was elected a Member in 1957. He was also a Member of The Institute of Marine Engineers and of The American Institute of Electrical Engineers.

G. O. W.

BRUDENELL PLUMMER BOYLE

Brudenell Plummer Boyle, who was born on the 7th August 1877, died on the 7th September 1957. He was born at Limavady in Northern Ireland, the second son of Major A. Boyle, J.P., and received his early education with a private tutor and at Coleraine Academical Institution. He then studied part-time at Belfast and Dublin Technical Schools, while serving apprenticeships with Combe, Barbour and Combe Ltd., Belfast, and with William Coates and Son, Dublin. On the completion of his apprenticeship with William Coates in 1900, he was appointed a sales engineer in the company, and in 1904 joined the British Thomson-Houston Co. as Assistant Manager in their Irish head office at Belfast, before taking up an appointment with the Bangkok Dock Co., Siam.

Returning to England in 1908, he joined the British Westinghouse Co. Most of his twelve years' service with the company was in the export headquarters in London, where he was in charge of the Colonial Division. In 1920 Mr. Boyle transferred to the Westinghouse Electric International Co. in London, where he became European Manager. His duties entailed fairly frequent visits to the United States and also took him to all parts of Europe. After fifteen years with the Westinghouse International Co., he became an Export Sales Engineer with the Brush Electrical Engineering Co., and he remained in this appointment until he retired in 1944. His active association with the industry was maintained for another seven years, during which he acted as a consultant with the British Engineers' Association.

Those with whom he worked, whether as subordinates, colleagues or competitors, all found him the typical Irish gentleman, charming, fair-minded and blessed with a quiet sense of humour. In committee he could be relied upon for steady, helpful counsel, speaking to the point without prolixity. He must have been one of the earliest motor-cyclists in Belfast. In those youthful days tennis and golf also claimed some interest, but throughout life the countryman's pleasures—fishing, shooting and ornithology—with his garden and workshop, were his chief relaxations. He was also a freemason, being a member of Kelvin Lodge, London. He is survived by his second wife and by the daughter and two sons of his first marriage.

Mr. Boyle joined The Institution as an Associate in 1901, and was elected an Associate Member in 1912 and a Member in 1928.

W. A. C.

ARTHUR ERNEST BREWERTON

Arthur Ernest Brewerton, who died on the 26th October 1957, was born on the 11th April 1885. He devoted his early years to acquiring a wide experience in both electrical and mechanical engineering, having received his electrical engineering education at the Northampton Institute (now the Northampton College of Advanced Technology) and his practical training with Rhodes Electrical Manufacturing Co. In 1905 he joined the Gilbert Arc Lamp Co. as a draughtsman and two years later transferred to the Brockie Pell Arc Lamp Co. In 1908 he was appointed an assistant engineer to the St. Marylebone Borough Council, and the following year he became a dynamo and motor designer to the Wolseley Sheep Shearing Co.

In 1914 he was appointed Chief Engineer to the Sperry Gyroscope Co., and was engaged in the manufacture and installation of gyro-compasses in naval and merchant ships.

In 1920 he moved to the Admiralty as a Principal Technical Officer. It was here that his inventive mind found the scope it required, and in the following years he produced many highly original inventions dealing with various phases of navigation and the finding and plotting of targets. At the outbreak of the Second World War, he was sent to Canada to organize the production of instruments in that country and in the United States.

Upon his retirement from the Admiralty in 1945, he established himself as a private consultant, and continued to invent and develop a number of highly successful ideas. Among them was a ship-telegraph system which is now widely employed by the merchant navies of the world.

Ernest Brewerton had a rare gift for the invention of mechanisms, particularly those concerned with the solution of mathematical problems. He was able to reduce these problems to their simplest form, at the same time converting them into mechanical and

electrical devices. He was an excellent mechanic, and he frequently crystallized his ideas by building a prototype of the new instrument in his own workshop. His work was in the classic pattern of the individual inventor, a pattern which he upheld even in these days of highly organized team work of research and development departments.

Among his inventions were the Brewerton course recorder, the Brewerton log, many refinements in gyro-compasses, and the 'true wind' indicator. The latter, produced in 1936, incorporated an ingenious electrical method for the continuous solution of varying-vector triangles, and was the forerunner of many such devices since widely used, particularly in anti-aircraft gunnery. Many of his inventions were used extensively, and he received a number of awards both from the Admiralty and from the Royal Commission on Awards to Inventors.

He is survived by his widow and two sons.

Mr. Brewerton joined The Institution as an Associate Member in 1911, resigning from this class in 1939, and he was re-elected as a Member in 1949.

F. J.

DOUGLAS RAYNER HARTREE

Douglas Rayner Hartree, PH.D., M.A., M.SC., F.R.S., Plummer Professor of Mathematical Physics in the University of Cambridge, died at Cambridge on the 12th February 1958. He was born on the 27th March 1897. He went up to Cambridge with an open scholarship to St. John's College, and after taking the Natural Sciences Tripos in 1922 became a Fellow of the College in 1924 and subsequently a Fellow of Christ's College in 1928. He was appointed Beyer Professor of Applied Mathematics in the University of Manchester in 1929, and in 1937 became the first Professor of Theoretical Physics in the same university. During the war years he was temporarily attached to the scientific staff of the Ministry of Supply. He was Kelvin Lecturer at The Institution in 1943. He returned to Cambridge as Plummer Professor of Mathematical Physics in 1946. In 1948 he was acting Chief of the Institute of Numerical Analysis of the United States Bureau of Standards, and in 1949 he was Higgins Visiting Professor at Princeton University.

Douglas Hartree gained early recognition in the scientific world by his outstanding work on atomic structure. The Hartree self-consistent field method of calculating atomic wave functions laid the foundation for the quantitative treatment of atomic structure and for the correlation of theory and experiment in the study of complex spectra. The early self-consistent field work involved extremely long and laborious numerical computations which Hartree carried out alone with tremendous tenacity of purpose. Moreover, in order to test his theory he chose a comparatively complex atom, the atom of caesium, the determination of the self-consistent field of which involved more than twelve months' solid computation. And in the art of computation Hartree had established a leading reputation in this country. Indeed, as a numerical analyst he had few equals.

The importance of the Hartree self-consistent field was recognized in 1932 when he was elected a Fellow of the Royal Society. It was the immensity of the task of carrying out the numerical calculations associated with his work on atomic structure that led Hartree to look into the possibility of mechanizing the solution of ordinary differential equations. He originated the first work in this country on the differential analyser and was responsible for the building of a model machine in the early 1930's which was subsequently followed by a large-scale machine. His strong advocacy of mechanical methods, and subsequently electrical methods, of handling mathematical problems automatically was largely responsible for the great upsurge of interest in the subject in this country. The results of this pioneering work can be seen at the present time when analogue and digital computers are playing so vital a part in scientific research and in industrial progress. It was through the medium of the early calculating machines that Hartree studied the behaviour of automatic process control systems, and his work in this field played a leading part in establishing the theory of automatic control and servomechanisms on a sound basis. In this country Hartree must be regarded as the founder of automation in all its aspects, not only in so far as the automatic control of processes is concerned, but also the widespread application of computers in so many different fields. For example, he was the first Englishman to programme the first high-speed digital computer, the Eniac, at the University of Pennsylvania, and this work provided a basis for his Inaugural Lecture at Cambridge in 1946. He saw immediately the enormous social importance of high-speed digital computers and stated publicly on one occasion that 'it may well be that the high-speed digital computer will have as great an influence on civilization as the advent of nuclear power'. It is already clear that in this matter, as always, his judgment was sound.

During the war Hartree made a vast number of contributions in a variety of fields. His theoretical work on the strapped magnetron, on the anomalous propagation of radar pulses, on fire control and on the automatic tracking of radar equipment, his chairmanship of the Ministry of Supply Servo Panel, his classical work on the steering of tanks, and his contribution to an innumerable list of scientific problems, bear testimony to his extreme versatility and his unbelievably high capacity for long and concentrated research work.

From 1946, during his occupancy of the Plummer Chair at Cambridge, Hartree concentrated on developing new techniques for the application of high-speed digital computers to problems in nuclear and atomic physics and in contributing to the basic logic and control of these machines. He acted in an advisory capacity to Dr. Wilkes, the Director of the Cambridge Mathematical Laboratory, and his staff. It is worthy of note that early this year he had been considering very actively the application of such machines to the design of complex railway signalling systems. He had a life-long interest in railways both model and real, and contributed on several occasions to the advancement of the railway system in this country—for example an early publication was concerned with the optimum train running times between Rugby and Euston.

Perhaps the outstanding characteristic of Douglas Hartree was his extreme humility and modesty. He was in his element when discussing problems with young research students, and it is impossible to conceive a more kind-hearted and good-natured teacher. He also had the unique characteristic of giving far more credit than was really due to his research students, and many of his collaborators must have felt that their personal contribution was often insignificant. Few men in the history of science have played such a highly significant part in the development of their subject in such an unobtrusive way. He is survived by his widow, a daughter and two sons.

Professor Hartree joined The Institution as a Member in 1945.

A. P.

FREDERICK HILL MASTERS

Major Frederick Hill Masters, O.B.E., T.D., died at Welwyn Garden City on the 29th January 1958. He was born on the 1st April 1883, at Hednesford, Staffordshire, where his father was in practice as a colliery surgeon. He was educated at St. Paul's and at Heidelberg, Germany. From 1901 to 1903 he studied electrical engineering at Finsbury Technical College under Professor Silvanus P. Thompson and continued later at King's College, London.

In 1906, after eighteen months' practical experience in electrical engineering at H.M. Dockyard, Chatham, and while still in his early twenties, he joined the staff of *The Electrician*. This marked the beginning of a career of fifty years in technical journalism, interrupted only by periods of war service. In 1910 he was appointed Assistant Editor of *The Electrician* and in 1919, on his return from service in the First World War, he became Editor.

In 1927, he transferred to the editorial staff of *Engineering* and apart from a period during the Second World War, he remained with that journal until he retired from full-time duties in 1956. In his professional life his observation extended beyond the confines of electrical engineering into other fields. His command of languages gave him an extensive view, and his leading and technical articles were informative on a wide range of subjects.

From an early stage in his career, Major Masters was interested in the application of electricity in the military sphere. In 1902 he joined the London Electrical Engineers, a voluntary unit formed

to assist in the adoption and operation of electrical equipment in the Army. He was granted a commission in the Territorial Army in 1910 and was mobilized in 1914. Serving throughout the 1914–18 War, he reached the rank of Major and was twice mentioned in dispatches. For his military services he was appointed an Officer of the Order of the British Empire. He served again in the Second World War, this time in a civil capacity, first with the Ministry of Economic Warfare and later with the Control Commission in Germany.

He had lived in Welwyn Garden City since 1922, where in the early days he took a leading part in local government affairs, being successively a member of the Parish Council and Chairman of a special Parochial Committee of the Rural District Council.

Frederick Masters was a man of wide intellectual and cultural interests. He read widely and was an interested and observant traveller. He was a shrewd commentator on current affairs. In a very happy and harmonious way his cultural interests were shared by his wife—a graduate in arts. They had three sons and a daughter. His second son is now on the editorial staff of the *Electrical Review*. Although reserved, Major Masters was a most amiable and pleasant companion and he will have left happy memories in the minds of all who enjoyed his friendship.

He joined The Institution as a Student in 1903, and was elected an Associate Member in 1909 and a Member in 1921. C. E. S.

CYRIL VIVIAN PEAKE

Cyril Vivian Peake died suddenly at his home at Framsden, Suffolk, on the 30th December 1957. He was born in London on the 24th June 1888, and was educated at Mill Hill. He received his technical education at the Central Technical College until 1909, when he became apprenticed to the General Electric Co., at the company's Witton works.

After completing his apprenticeship, Mr. Peake served with the consulting engineers, Moffat and Rosher, for a year until, for health reasons, he visited Canada.

In 1914, shortly before the First World War, he rejoined the General Electric Co., and when war was declared he was disappointed in being unable to take part in active service. His training and ability were invaluable in the war effort of the company and he was appointed Chief of the Test Department in 1917, which post he held until 1944, when he took over the management of both the Test and Inspection Departments. From this position he retired in 1949.

Mr. Peake combined a great charm of manner and a lively humour with outstanding loyalty and integrity. He was always most considerate for those in trouble, but he was satisfied only with the very best in motives, behaviour and work, and never spared himself to achieve his exacting standards. By his position and his character Mr. Peake exerted a great influence on many hundreds of apprentices, now spread throughout the world, who are ever ready to acknowledge their indebtedness to him.

His early interest in music and drama suffered greatly by his deafness—a handicap which made social contacts difficult and which narrowed the range of outside activities, but he was always keenly interested in art and literature and later made woodwork a hobby. Mr. Peake was known for his interest in homoeopathy, which he practised for the benefit of many. His years of retirement were full of activity in community service to his district and his church, in which he was joined by his wife, who survives him. He leaves also a son and a daughter.

Cyril Peake joined The Institution as a Graduate in 1912, and was elected an Associate Member in 1915 and a Member in 1919.

A. B. C.

JOHN PATRICK ARTHUR MELDRUM

John Patrick Arthur Meldrum, O.B.E., B.SC., who died as the result of a road accident on the 20th January 1958, was born on the 3rd September 1903. He was educated at Rugby school, and, after a period with the Ailsa Shipbuilding Co., he went to Glasgow University, where he obtained an honours degree in mechanical engineering. He was a vacation apprentice with Metropolitan-Vickers Electrical Co. in 1924, and rejoined them to continue his professional training as a college apprentice in 1926, remaining with the same company for his entire professional life.

On completion of his apprenticeship, Meldrum joined the Switchgear Engineering Department. In 1930 he transferred to the Switchgear Sales Department, on whose behalf in 1939 he visited Australia and the United States on a difficult but successful mission. Immediately on his return, Meldrum received his call-up papers as a member of the Supplementary Reserve of Officers, and he served with the Royal Corps of Signals. Initially stationed at Catterick, he soon became Adjutant; later, with the rank of Lieutenant-Colonel, he was in France and Germany with the invasion forces, was appointed an Officer of the Order of the British Empire and was mentioned in dispatches.

A few months after returning to Trafford Park in 1945 as Assistant Sales Manager, Meldrum was appointed Sales Manager, Switchgear Department; in 1953 he became Manager for all home sales activities of the company, followed two years later by election to the Board of Metropolitan-Vickers. He was also a director of a number of associated companies, including A.E.I.—John Thompson Nuclear Energy Co., a member of several B.E.A.M.A. committees and a member of the Association of Short-Circuit Testing Authorities' Council.

Meldrum's success in his career was largely due to his energy and organizing skill, and to his facility for getting on with people, aided by a sense of humour which was a real asset in difficult situations. To his colleagues he was always a considerate, generous and most loyal friend.

In private life, outdoor activities were Meldrum's principal interests. He was a good shot and enjoyed spending weekends rough or pheasant shooting. He was knowledgeable about all kinds of wild life and was an expert gardener. He and his wife, Margaret, who died in the same accident, leave a married daughter and two granddaughters.

Mr. Meldrum joined The Institution as an Associate Member in 1940 and was elected a Member in 1949. C. H. F.

JOHN CAMERON RENNIE

John Cameron Rennie, B.SC.(ENG.), who died on the 31st October 1957, was born in Glasgow on the 19th January 1887. Soon after his birth his father was appointed to be in charge of the Board of Trade Electrical Standards Laboratory in Whitehall, and the family accordingly moved to London. He was educated at St. Mark's School, Chelsea, and at the City of London School. On leaving school he entered the Northampton Institute, London, gaining the first entrance scholarship and finally graduating with the degree of B.Sc.(Eng.) of London University in electrical engineering. During his four-year college course he served two periods of apprenticeship, with British Westinghouse Electric and Manufacturing Co., Manchester, and Peter Pilkington, Preston, respectively.

His first appointment, in 1909, was with Siemens Bros. Dynamo Works Co., Stafford, but he soon found his true vocation with the firm of Boult, Wade and Tennant, the well-known chartered patent agents of Hatton Garden, London. Joining them in 1910 as a technical assistant, he was made a partner in 1927 and at the time of his death had been with the firm over forty-five years.

In the 1914–18 War he was commissioned in the R.N.A.S. as a Lieutenant, becoming a Captain (Technical) in the Royal Air Force when the R.N.A.S. and R.F.C. were amalgamated. In his service at the Air Ministry he did much to initiate and speed up many desperately needed improvements to the engines for fighting aeroplanes. Some few years ago a special lunch was given in his honour by one of the largest firms of aeroplane builders, in recognition of his professional services to them over many years. He also carried out the patent work for Baird's inventions throughout all the early development of television.

He always took the greatest interest in his old college, founding the Old N'Ions Association while still a student, and later he

presented the annual Rennie Prize for second-year students. He was, more recently, appointed to the Governing Body of the College.

His health had been poor for many years past, and his trip, with his wife, round the world in 1951–52 unfortunately did not have quite the favourable results which were hoped. He was a man whose work was all absorbing and left small time for other interests. In sickness, as in health, he was at all times serene and self-controlled and no one could ever imagine him out of temper. These qualities made him widely liked and respected and found him the most sympathetic of companions to those who were privileged to be his friends.

He is survived by his widow and three sons.

Mr. Rennie joined The Institution as a Student in 1909, was elected an Associate Member in 1914 and a Member in 1928. He served as Chairman of the London Students' Section 1912–13. He was also a Member of The Institution of Mechanical Engineers and a Fellow of the Chartered Institute of Patent Agents. R. E. D.

ROBERT JOHN SOWTER

Robert John Sowter, B.SC., A.R.C.S., Barrister-at-Law, who died on the 30th June 1957, was born on the 25th October 1875. He received his technical training at Bradford Technical College and at the Royal College of Science, South Kensington, where he became Assistant Professor in Physics in 1896 on the completion of his course.

In 1898 he was appointed a lecturer in electricity and magnetism at South Norwood Polytechnic, Assistant Examiner in Physics to the University of London, and examiner in electricity and magnetism to the Civil Service Commissioners, London. In 1898 there were three candidates admitted to the Patent Office and Mr. Sowter obtained the highest marks of the three, with especially high marks in physics and electricity. He was appointed as an examiner, in which position he remained until 1919, when he accepted a position in the Civilian Experimental Department of the Signal School, Portsmouth, as a Senior Engineer, for duties in connection with patent matters, particularly as regards radio-signalling equipment. At this time there was very rapid development of thermionic valve devices for naval use based on, and in continuation of, the pioneer work carried out during the First World War. This involved complex patent considerations, and Sowter took up the work with enthusiasm. He prepared subject-matter for patents based on work at the Signal School, and conducted intensive analyses of literature and of inventions relating to work done elsewhere. This work was helpful to the Admiralty in regard to the many post-war problems which arose with the industry and with inventors generally. He was among the Admiralty officials whose work was specially commended by the Board in connection with the arbitration leading to the settlement of a company's claim in respect of royalties in 1929. He retired from the Admiralty in 1932, a few years before normal retiring age, by reason of a partial breakdown in health.

He was most friendly and helpful to his Signal School colleagues, always willing to assist and to advise them as regards both technical and general matters. But, apart from his work, he was somewhat reserved. He played tennis and golf to a moderate degree and was interested in all forms of sport. In earlier days he was an enthusiastic motorist.

Mr. Sowter joined The Institution as an Associate Member in 1920 and was elected a Member in 1922. He was also a Fellow of the Physical Society. G. S.

GUILHERME DUMONT VILLARES

Dr. Guilherme Dumont Villares, who died in São Paulo, Brazil, on the 21st September 1957, was a nephew of Santos Dumont, the pioneer aviator. Born in Ribeirão Preto in the state of São Paulo on the 29th May 1887, he was educated at a preparatory school in São Paulo before coming to England to study at Kelly College, Tavistock. This was followed by a three-year engineering course at Crystal Palace Engineering School, Sydenham, after which he went to Germany to gain practical experience with Siemens-Schuckert.

In 1910 he returned to Brazil to take up an appointment as Commercial Engineer with the São Paulo Light and Power Co., with whom he spent forty-two years. He specialized in commercial engineering and tariff studies, and at the time of his retirement a few years ago he occupied a senior position in the Commercial Department.

Among his fellow citizens, he was best known and most beloved for his great-hearted outlook and philanthropic activities. Both he and his wife, Maria Luiza, devoted time, energy and money to helping orphan children. After the 1932 revolution in Brazil he provided for the care and education of no less than seventy children who had been rendered fatherless during the uprising, and several girls were actually adopted and brought up as his own daughters. In many other ways he worked for and assisted the charitable institutions of São Paulo, all of which owe him an enduring debt of gratitude. He loved the country and had a small farm close to the city where he could look after some of his young protégés. In every sense he was one of 'nature's gentlemen'.

Dr. Villares joined The Institution as a Student in 1907, and was elected an Associate Member in 1912 and a Member in 1935. A. H.

REGINALD WEAVING

Reginald Weaving, who died on the 21st November 1957, was born on the 9th December 1882. He was educated at King Edward's Grammar School and Bishop Ryder's School, Birmingham, and subsequently he took a three-year electrical engineering course at Birmingham Technical College. His early engineering experience was gained with a number of firms including Coventry Lighting and Engineering Co., Compagnie Internationale d'Électricité, Liège and London, and Perkins (Engineers) Ltd., Peterborough, where he was Chief Electrical Engineer for seven years.

In 1911 he joined Ferranti Ltd. at Hollinwood, where he specialized on power transformer design and manufacture, and in 1916 he was appointed Chief Assistant Engineer of the firm's Switchgear Department. In 1919 he was appointed Engineer and Manager of the Transformer Department of the English Electric Co., Coventry, in which position he remained until he joined Crompton Parkinson Ltd., Chelmsford, in 1927 as Manager and Chief Engineer of a similar department. During this appointment he gave a great deal of thought and attention to transformer on-load tap-changing gear, which culminated in the Crompton-Weaving patents.

In 1932 the British Electric Transformer Co. was acquired by Crompton Parkinson, who transferred their Transformer Department to the B.E.T. at Hayes, Middlesex, where Mr. Weaving was appointed Chief Engineer and Manager. He followed up his interest in on-load tap-changing gear by sponsoring the development of the use of mercury switches to provide maintenance-free current breaking. He subsequently became General Manager and a Director of the British Electric Transformer Co.

In his earlier years he was a keen amateur soccer footballer, playing as a forward with the Reading club; and he was also an accomplished swimmer. In middle life he played golf, but never claimed he brought more than enthusiasm to it or obtained more than good exercise from it. His engineering instincts made it natural that he should take an enthusiastic interest in the early days of motor-cycling and motoring, and he was never happier than when telling of the trying behaviour of many early models in the long line of his mechanically propelled mounts, although in more recent years his taste ran to a powerful car driven fast.

He was slightly built, but had enormous courage and tenacity and a tremendous appetitite for work. He made business visits to New Zealand and Australia by sea during the latter part of the Second World War, and made further visits to them and to South Africa in post-war years. He is survived by his widow and a daughter.

Mr. Weaving joined The Institution as an Associate Member in 1913 and was elected a Member in 1920. L. S.

MONOGRAPHS AND PAPERS
published individually this month

Synopses of monographs and papers published individually before the next issue of the Journal are given below, and, unless otherwise stated, their dates of publication are this month. Reprints of all papers are available about two months after publication in the Proceedings. The prices shown below are post free. When ordering please quote serial number of paper or monograph. Books of 8 vouchers may be obtained from the Secretary, price 10s. each.

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MONOGRAPHS

The Fields Associated with an Interface between Free Space and an Artificial Dielectric *Monograph* 300 R

J. BROWN, M.A., PH.D., *and* J. S. SEELEY, B.SC.(ENG.), PH.D.

In most respects artificial dielectrics behave in a similar way to normal solid dielectrics. A complication is sometimes observed in that apparent phase discontinuities occur at the interface between free space and an artificial dielectric, such discontinuities arising from the excitation of reactive fields near the interface. It is shown that the behaviour can be analysed in terms of evanescent waves inside the dielectric and in free space, and detailed calculations are given for the metal-strip type of delay dielectric. Measured values of the parameters of an equivalent circuit representing the free-space/artificial-dielectric interface are shown to agree with calculated values within the limits of experimental error.

The Use of Equivalent Secondary Sources in the Theory of Ground-Wave Propagation over an Inhomogeneous Earth *Monograph* 299 R

Z. GODZIŃSKI

The monograph deals with the propagation of a vertically polarized ground-wave over an inhomogeneous spherical earth. On the basis of approximate boundary conditions and a specially chosen auxiliary function in Green's theorem, the integral equation for the attenuation function is derived. A general method of solving this integral equation by numerical techniques for paths composed of a number of homogeneous sections is discussed. It is proved that the result is in agreement with the reciprocity theorem.

The actual field is shown to be the superposition of the fields generated by the primary source and by secondary sources distributed along the path. It is demonstrated that the distributed secondary sources may be approximately replaced by a number of suitably chosen equivalent secondary sources. An approximate method of calculation based on this property is introduced. The method is discussed in some detail in two cases: when the paths may be regarded plane and when they extend into the diffraction zone. The proposed method makes possible a simple and rapid calculation of field strength in many practical cases. It may be used for any phase characteristic of the complex permittivity of the soil.

A Generalized Form of the Aerial Reciprocity Theorem *Monograph* 301 R

J. BROWN, M.A., PH.D.

The reciprocity theorem which relates the transmission and reception properties of an aerial is extended to give information on the phase and amplitude of the signal received by the aerial for an incident plane wave of any polarization. The monograph includes a rigorous proof based on the Lorentz reciprocity theorem for electromagnetic fields.

An Analysis of Commutation for the Unified Machine Theory *Monograph* 302 U

C. V. JONES, M.ENG., B.SC.

The logical treatment of the unified machine theory is of such merit that it seems likely that it will eventually supersede the classical treatment entirely. The unified theory is, however, at present deficient in two respects. It requires two primitive machines, a slip-ring primitive and a commutator primitive, as the bases for analysis, and it tacitly assumes the existence of a perfect commutator. The mechanism of commutation is entirely neglected.

The author gives a new theory of commutation, which not only elucidates this mechanism, but enables the performance of any machine or machine system to be developed from one basis only, the simple case of two coils with relative angular movement.

Each stage of the analysis is supported with a comprehensive series of experimental results. The tests involved introduce some interesting problems, and a new method for the measurement of the coefficient of self-inductance for direct currents is developed.

Design of Sampling Servo Systems in the z-Plane *Monograph* 303 M

T. M. H. REENSKAUG *and* J. H. WESTCOTT, PH.D.

The authors describe the basic concepts of the sequence transform theory, particularly stressing the non-physical form of samples assumed for mathematical convenience. In dealing with inverse transforms, some typical transient modes due to poles of the transfer function Y(z) are shown.

It is shown that the root-locus method is well suited to the design of sampling control systems; also that the passage of

time can be described by a system of moving zeros in the complex z-plane. This provides a complete picture of the response of a system to a given output, both at the sampling instants and between them.

Barker has suggested a particular form of stabilizing network which has the advantage of introducing a modifying function that is independent of the rest of the system. This work has been extended by showing the limitations of the method and by giving a table of the networks required to realize the function.

Finally, two examples are worked out in some detail to illustrate the theory, and a brief description of an experimental unit is included for completeness.

PAPERS

Operational Experience at Calder Hall *Paper* 2594 S: *Part A*

K. L. STRETCH, M.A.

The paper describes the programme carried out to commission and operate the Calder Hall nuclear power station from the time when reactor 1 was taken over by the operations branch in May 1956, until the complete unit was on line at full power. Detail of the methods of carrying out particular aspects of the experimental work is left for other authors; the emphasis in this paper is on the relevance of the tests to the successful operation of the Calder Hall project in particular and the prospects for nuclear generation of power in general.

To be read on the 16th April 1958

A Survey of Performance Criteria and Design Considerations for High-Quality Monitoring Loudspeakers

Paper 2604 R: *Part B*

D. E. L. SHORTER, B.SC.(ENG.)

Loudspeakers employed for monitoring purposes in broadcasting and recording studios are designed to give the highest possible quality of reproduction. The author discusses the various criteria which may be applied to the performance of such loudspeakers, as well as the relationship between the characteristics measured under free-field conditions and the response as subjectively assessed in the normal working environment.

While the degree of realism achieved in sound reproduction can only be judged aurally, even subjective assessments can be misleading unless carried out under controlled conditions and with clearly defined terms of reference. The author describes the procedure adopted in the B.B.C. for such tests.

To be read on the 23rd April 1958

A Method of Measuring and Displaying Generator Rotor Angle
Paper 2602 M: *Part A*

J. N. PREWETT, M.A.

The equipment was designed for stability tests at Cliff Quay generating station. The method chosen was one which might, with some modifications, be suitable for permanent installation in any power station.

The instantaneous angular position of the rotor is determined using photo-electric methods, and a reference voltage is derived from a voltage transformer connected either to the generator output terminals or to one of the station 132 kV busbars. The phase angle between these two electric signals is measured by a phase-sensitive detector using transistors, the d.c. component of whose output is used to drive a pen recorder having a high speed of response. The overall accuracy of the system is $\pm 6°$.

The photo-electric method has some disadvantages, and a magnetic method would be more suitable for long-term operation. Displaying rotor angle on a pen recorder was found to be a very useful aid to the control engineer in determining whether his action had restored generator stability.

To be read on the 29th April 1958

Generator Rotor Angle Measurement by Stroboscopic Means
Paper 2576 M: *Part A*

E. B. POWELL *and* M. E. HARPER

The stroboscopic equipment described in the paper was originally designed and used for observation of machine rotor angles under conditions where recording was not required. Further development of the apparatus, together with the establishment of a cine-film recording technique, extended its use to the recording of rapid rotor-angle changes.

A cine camera driven at 50 frames/sec is used to obtain a cine-film recording of the stroboscopic image. This permanent pictorial record of the rotor movement during the period of observation may be projected onto a screen in the usual way, or an angle/time curve may be drawn from an inspection of the film.

The particular value of this method lies in the accuracy with which very rapid changes of rotor angle are recorded. It suffers from a disadvantage since viewing of results is delayed until the film has been developed. The apparatus has been found most helpful in a number of transient tests on turbo-generators.

To be read on the 29th April 1958

Power-System Phase-Angle Measurements *Paper* 2598: *Part A*

F. MORAN, M.SC.

The paper describes an instrument developed to record the phase variations between two 50 c/s signals with a scale of $\pm 12\frac{1}{2}°$. The instrument was used during generator stability tests to record phase variations between the reference busbar voltage and a voltage at a remote point in the system undisturbed by the tests. The measurements were required to correct the test-generator rotor-angle measurements.

To be read on the 29th April 1958

The Design of the 330 kV Transmission System for Rhodesia
Paper 2583 S: *Part B*

F. C. WINFIELD, M.ENG., T. W. WILCOX, *and* G. LYON, M.SC.(ENG.)

The Kariba Gorge hydro-electric scheme now under construction by the Federal Power Board of Rhodesia and Nyasaland will provide the power for a major increase in electrification in the Federation. Outputs of 1 200 MW and 8 000 kMWh per annum or more can be generated, and a 330 kV system is being built to transmit the power to the consuming centres over distances of above 300 miles. The authors outline the conditions governing the design of the system, describe the steps taken to select the system voltage and other main features, and discuss some of the factors affecting the characteristics and design of the equipment.

To be read on the 30th April 1958

A New Cathode-Ray Tube for Monochrome and Colour Television *Paper* 2661 R: *Part B*

D. GABOR, DR.ING., F.R.S., P. R. STUART, *and* P. G. KALMAN

A flat thin television tube for monochrome or colour, whose thickness is only about one quarter of its screen diagonal, has been developed to the point at which the feasibility of its essentially novel features could be tested singly, and partly in combination. In the flat tube, the electron beam is launched vertically downwards. A line-deflection system imparts to it a pendulating motion in a vertical plane, and a reversing lens turns this plane by 180° and increases the deflection angle by a factor of about four. Just before reaching the screen region the beams are turned into the vertical direction by a magnetic collimator. The beams now enter a narrow space between the phosphor screen and a *scanning array*, consisting of parallel horizontal conductors arranged in a plane parallel to the screen. At a certain level the beam is thrown against the phosphor screen by an electric field, which travels downwards with the speed of the frame scan. The extensive electron-optical development work is described in detail, and mention is made also of special technological problems raised by the new tube design, and of their solution.

To be read on the 14th May 1958

Operating Experience with a Transistor Digital Computer *Paper* 2593 M: *Part B*

R. C. M. BARNES, B.SC.(ENG.), *and* J. H. STEPHEN, PH.D.

A small digital computer using only transistors as active circuit elements has been operating for a year. The paper describes the performance of this computer and, in particular, the failure rate of point-contact transistors. Earlier information on this computer is supplemented by details of circuit developments.

Date of reading not yet fixed

Assessment of Speech Communication Links *Paper* 2605 R: *Part B*

D. L. RICHARDS, B.SC.(ENG.), *and* J. SWAFFIELD, PH.D., B.SC.(ENG.)

The paper examines the mechanism of conversation over a speech link and deduces a sequence of criteria each applicable over an appropriate range of performance. A general assessment method follows from this and the corresponding experimental techniques (which depend on the use of ordinary untrained subjects) and some applications are discussed. Some existing assessment methods can be fitted into the framework provided by the general method and can then be used with increased confidence.

Date of reading not yet fixed

TECHNICAL PUBLICATIONS

BRITISH STANDARDS

Copies of the following publications can be obtained from the British Standards Institution, 2 Park Street, London, W.1. The prices given are post free.

B.S. 2899: 1958 **Vulcanized Rubber Insulation and Sheath (Including Polychloroprene) of Electric Cables** 5s.

This specification replaces the clauses on quality of rubber insulation and sheath in the existing Standards. The principal change reduces the rubber content of general-purpose insulation from 70–80% to 50–60% by volume. The new compound is similar to Type 2 specified in Defence Specification DEF.15 used by Government departments.

The Standard also gives requirements for fire-resisting and ozone-resisting insulation, and for four types of sheath. The specified rubber content of general-purpose sheath is somewhat less than is required by B.S. 7: 1953. Methods of test, similar to those in B.S. 7, are prescribed for the various types of insulation and sheath.

One result of the reduced rubber content of general-purpose insulation, dealt with in the amendments to B.S. 7 and other specifications, is a reduction in the insulation resistance of finished cables. The new values are, however, still considerably greater than those accepted for corresponding p.v.c.-insulated cables, and The Institution of Electrical Engineers has not found it necessary to modify the Wiring Regulations.

B.S. 1732: Part 2: 1958 **Domestic Electric Steam Irons** 5s.

This new publication establishes a minimum standard of safety and a satisfactory standard of mechanical and electrical construction for domestic electric steam irons. The present Standard for ordinary electric irons (B.S. 1732: 1951) will shortly be revised and published as Part 1 of the same specification.

Part 2 sets out requirements for two types of iron—*drip feed* and *boiler*. The heating elements of both types are for operation in the voltage ranges 30–250 volts (r.m.s.) a.c., and 50–250 volts d.c.

After laying down constructional requirements, the Standard provides a set of rigorous tests to be carried out by the manufacturer in order to ensure that the irons are fit for their job. There are tests relating to loading, insulation, mechanical shock, pressure, earthing, temperature, flexible-cord guard and cord anchorage, inaccessibility of live parts, endurance, and vibration.

B.S. 2960: 1958 **Dimensions of 3-phase Electric Motors with Ventilated Enclosures** 6s.

This new British Standard will ensure complete mechanical interchangeability of motors of different make. It applies to electric motors with enclosures of the protected, screen-protected and drip-proof types.

In addition to the advantages of interchangeability, the publication breaks new ground in the introduction of standard-dimensioned motors using the recently developed Class E insulating materials. This means that for a given power output motors built to the new Standard will be appreciably smaller and lighter. This reduction in size will, of course, bring about an appreciable saving in production costs due to economies in materials. Many manufacturers of the new motors are also introducing new production techniques which will still further improve productivity.

The Standard applies to 3-phase 50 c/s squirrel-cage

ventilated motors with maximum continuous ratings in the range 1–40 h.p. (at 1 500 r.p.m. synchronous speed) at voltages up to 650 volts. The motors are of the foot-mounted, flange-mounted and skirt-mounted types.

B.S. 2928: 1957 **Shockproof X-Ray Cable Terminations and Receptacles Operating at 55 kV Peak** 4s. 6d.

This is the latest addition to the series of British Standards which is being prepared for medical and industrial X-ray equipment. It concerns shockproof high-voltage cable terminations and their corresponding receptacles for operation at 55 kV peak for use in X-ray equipment. Detailed drawings standardize dimensions to ensure interchangeability and safe and efficient operation. Materials are not, however, specified.

The type of terminal specified has three contact pins, and the Standard lays down the manner of connecting the pins and sockets to the filaments of X-ray tubes and specifies the appropriate markings. Guidance is given on a procedure for gauging the accuracy of the sockets.

High-voltage rating and contact rating are specified; and there are detailed descriptions of the manner of taking samples for test, the testing procedure and the appropriate testing equipment.

B.S. 2949: 1958 **Marine Electric Motors and Generators other than for Propulsion** 8s. 6d.

Prepared at the request of the committee of The Institution of Electrical Engineers responsible for the 'Regulations for the Electrical Equipment of Ships', this Standard deals with marine electric motors and generators (other than those used for propulsion) and rotary convertors. The machines are rated at 1 h.p., 0·75 kW or 0·75 kVA per 1 000 r.p.m. or greater. The Standard places no upper limit on the power rating.

The machines dealt with are suitable for specified service conditions and may be assigned a maximum continuous rating or a short-time rating. The enclosures which may be employed are classified, and constructional and performance requirements are specified.

Alignment with B.S. 2613, 'The Electrical performance of Rotating Machinery' has been maintained wherever possible. The permissible temperature rises, based on a 50° C ambient cooling air temperature, give—in general—total temperatures for windings 5° C lower than those in B.S. 2613. Classes A, E and B insulation only are recognized, and for temperature rises a distinction is drawn between totally enclosed machines and machines with other types of enclosure..

B.S. 2950: 1958 **Cartridge Fuse-Links for Telecommunication and Light Electrical Apparatus** 4s. 6d.

The fuse-links dealt with in this new British Standard supersede the Type B fuses which were specified in B.S. 646: 1935, which has now been revised. They have the same dimensions as the old Type B fuses, but the performance differs in two important respects. Firstly, the rated voltage varies according to the rated current, from 1 000 volts for the smaller currents (50–250 mA) down to 32 volts for currents of 25 amp. Secondly, since under the conditions in which these fuse-links are intended to be used the prospective fault current is restricted, the breaking-capacity test is made at a prospective current that does not exceed ten times the rated current of the fuse-link.

The main object of the Standard is to specify cartridge fuse-links of a quality that experience has shown to be adequate for their purpose, without adding to their cost or requiring extensive proving tests.

A preferred range of rated currents and voltages is given together with an optional colour code.

B.S. 1259: 1958 **Intrinsically Safe Electrical Apparatus and Circuits for Use in Explosive Atmospheres** 4s.

The principal feature of this revision of B.S. 1259: 1945 is the introduction of a list of flammable gases and vapours in respect of which apparatus may be accepted for test and possible subsequent certification. These gases and vapours are placed in four classes (methane, pentane, ethylene, hydrogen) for the purposes of tests which are described in an appendix.

The Standard specifies general requirements for all types of electrical equipment which may be regarded as being safe for use in dangerous explosive atmospheres (such as in coal-mines, oil and petroleum stores and in industry generally) by virtue of their electrical design and circuit characteristics—as opposed to equipment in a flameproof enclosure (for which the appropriate Standard is B.S. 229).

The term *intrinsically safe* is defined, and the Standard includes information and requirements relating to the certification of equipment so described.

Three appendices provide much useful information on the principles and tests for intrinsic safety, together with a full list of references to technical reports and publications issued by the Electrical Research Association and the Safety in Mines Research Establishment.

E.R.A. REPORTS

Copies of the undermentioned E.R.A. Reports can be obtained from the British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey.

C/T116 **The Testing of Wind-Driven Generators Operating in Parallel with a Network** by D. E. Villers. 18s.

A brief review of the problem of testing full-scale wind-driven generators, under natural wind conditions, shows that the steady-state relationship between generator output and wind speed may be found by a simple method.

Tests carried out on a 10 kW machine connected to the public supply network are described, and the results are compared with the calculated output characteristics of the machine.

Suggestions are made for further work on the testing of wind-driven machines connected to a network or running in isolation.

D/T102 **Synthetic Resin Cements for Glass-to-Metal Seals for Use in Flameproof Enclosures** by H. F. Church. 6s.

This report describes a preliminary examination of the properties of polyester, ethoxyline and thiokol resins and compounds and draws conclusions as to their suitability for use in cementing glass to metal in windows in flameproof enclosures.

G/T306 **The Variables that Arise in Contactor Testing** by H. W. Baxter and Z. Cetnarowicz. 12s. 6d.

E.R.A. researches on contactors have revealed a number of important variables which must be accurately controlled if

consistent results are to be obtained. These are listed, together with some notes on the probable effect of a change in the variable and any relevant conclusions. Where a variable is likely to affect the performance of a contactor but has not yet been the subject of investigation by the E.R.A., a note to this effect is included. The effect of a change of variable may depend on the kind of test, since for a test involving thousands of operations (e.g. a test of contact wear) random switching might be permissible, but it might be intolerable for a test of, say, contact welding.

G/XT160 **A Simple and Inexpensive Emission Regulator for Ionization Gauges** by M. P. Reece. 4s. 6d.

The ratio of positive-ion current to electron current in an ionization gauge is proportional to the pressure, so that, by keeping the electron current constant, the pressure may be determined directly from the positive-ion current. It is, therefore, desirable to control the filament current of an ionization gauge to give a constant electron emission. Since changes in pressure often affect the emission of the filament, an automatic regulator is by far the most convenient way of keeping the electron current constant, and makes the gauge particularly useful for continuously monitoring pressure in a vacuum system.

There are available a number of commercial regulator units, but these are usually rather expensive. A large number of regulators have been described in the literature, but the one described in this report is exceedingly simple and can be made from readily obtainable components.

L/T341 **Reverse Driving of Short Arcs** by A. E. Robson. 6s.

Cobine and Gallagher made comprehensive investigations of the dependence of reversal conditions on current, magnetic field, pressure, nature of gas and cathode material. Himler and Cohn discovered that another parameter affected the reversal of an arc, namely the separation of the electrodes. They found that when the distance between the electrodes of a short copper arc in air was decreased there was an increase in the pressure necessary to change the motion from reverse to ampere.

The authors have investigated the motion of a copper arc in air, varying the separation of the electrodes between 0·5 and 2 mm, the current from 0·5 to 5 amp and the magnetic field up to 5000 gauss.

N/T74 **Some Magnetic Properties of Dilute Anisotropic Ferromagnetic Alloys** by Professor W. Sucksmith. 6s.

This report is concerned with the magnetic properties of very small particles of iron which are precipitated out of dilute solid solution in copper. An apparatus is described for measuring resonance and coercivity in the very low intensities of magnetization encountered. The work described in report Ref. N/T64 has been extended to the development of anisotropic alloys with high coercivities, produced by cold drawing of the alloys. The results are discussed in the light of existing theories.

D.S.I.R.

Road Research Technical Paper No. 39. Traffic Signal Settings. 2s. 6d.

This is an interesting report describing research carried out at the Road Research Laboratory to investigate the problem of the optimum setting of fixed-time signals for road intersections. Although six out of every seven signals in Great Britain are vehicle-actuated, they become effectively fixed-time signals when traffic is heavy and the green periods are of maximum length. It is perhaps surprising to learn from the introduction to the booklet that in the United States fixed-time signals are much more numerous than vehicle-actuated ones. The use of traffic signals in Great Britain is still increasing and there are at present more than four thousand installations, about a thousand of these being in the Greater London area.

The investigators used the former pilot model Ace computer at the National Physical Laboratory for simulating the behaviour of traffic and traffic signals at a road intersection. The traffic was considered as arriving at random at a point far enough from an intersection to be out of the area of the disturbance caused by it. The delay to traffic was computed by counting the number of vehicles in the queue at fixed intervals of time and multiplying this number by the time interval. Formulae are given for the average delay per vehicle and optimum cycle time to produce the least delay to all traffic using a crossing. The report summarizes the procedure for optimum setting of traffic signals based on the formulae and tables included in it; this has been tested at actual road crossings and found to be satisfactory. The booklet is obtainable from Her Majesty's Stationery Office.

NATIONAL RESEARCH DEVELOPMENT CORPORATION

Report for the Year 1956–57 2s.

The Annual Report for 1956–57 of the National Research Development Corporation has recently been published and is available from Her Majesty's Stationery Office. The Corporation was established under the Development of Inventions Act, 1948, to encourage the development both of inventions made in public research laboratories, and of other inventions which the Corporation consider are not being sufficiently exploited. The Corporation is thus primarily concerned with research carried out by Government Departments, the universities and industrial research associations, but it may sponsor the development of inventions from private firms or individuals if it considers such action to be in the public interest. The Corporation can finance the construction of prototypes and pilot production.

There are several items of interest to electrical engineers in the Report. The Corporation's largest single project has been electronic computers and this was begun in 1949. All sixteen computers commissioned by the Corporation in previous years are now complete and in operation. The development of an advanced business-type computer and data-processing system using magnetic cores and transistors is progressing satisfactorily. A new project for the development of an extremely high-speed computer (several hundred times faster than those at present available) is under consideration.

Another item, which has received wide publicity in the national Press, is Dr. Gabor's television cathode-ray tube. This involves a revolutionary system of electron optics and should, when development is complete, lead to a comparatively flat cathode-ray tube without a 'stalk', which can be hung on the wall. A paper about this invention will be read before the Radio and Telecommunication Section on the 14th May (see also p. 206).

The Corporation is also sponsoring the development of fuel cells and of the variable-speed induction motor, about which information has already been given to The Institution by

Professor F. C. Williams and Dr. E. R. Laithwaite; a project for solving problems in the design of computer control of machine tools, which is in the hands of Dr. B. V. Bowden and colleagues at the Manchester College of Science and Technology; an electrical ignition system for the Ministry of Supply, which is being developed at the Royal Aircraft Establishment; and printed electrical circuits, the further development of which is being carried out by Dr. Paul Eisler for an industrial firm.

NATIONAL COAL BOARD

Information Bulletin No. 57/191 **Charging and Changing of Locomotive Batteries Underground**

Battery-powered electric haulage locomotives have been used in collieries for the last twenty-five years and have increased rapidly in number since the end of the Second World War. Though comparable in performance with other types of electric locomotive, they suffer from the disadvantage that the battery has limited capacity. The operating efficiency is therefore determined largely by the speed of changing and recharging the batteries. The object of the report is to make suggestions for the improved design of battery-charging stations, and to this end it surveys the existing practice in twenty-eight installations.

The time required for changing the batteries was found to vary from 3 to 40 minutes in the different installations, and the report examines the merits of the 'roll-off' and 'lift-off' methods, the arrangement of stands with regard to the available space, the position of sockets, the use of mobile stands, the stability of the colliery floor, the design of cranes and the layout of the track. The battery-charging equipment is then considered, the two-step method of charging being generally favoured, since it avoids the possibility of overheating which is inherent in the single-step method and enables a battery to be fully charged within a single 8-hour shift. The rectifiers at present in use are either selenium or mercury-arc, but the report mentions that germanium rectifiers, which will be smaller and more efficient than the selenium type, should be available in the near future. The report describes the various charger circuits and protective systems in use, and concludes with some recommendations on maintenance and repair facilities.

The report may be obtained free of charge from the National Coal Board, Hobart House, Grosvenor Place, London, S.W.1.

SOME RECENT BOOKS

BRITAIN AND EUROPE

A Study of the Effects on British Manufacturing Industry of a Free Trade Area and the Common Market

THE ECONOMIST INTELLIGENCE UNIT. 1957. 288 PP. 15S.

This survey was prepared by the Economist Intelligence Unit on behalf of the Britain and Europe Fund, which was established early in 1957 and which was sponsored by a number of leading men in industry, commerce, trade associations and trade unions.

The work was completed in a matter of a few months, and the book is a remarkable testimony to the zeal with which the authors set about their task. The audacious statistical estimates, the enthusiastic support of the original proposals concerning the Free Trade Area, and the optimistic assumptions about the future of economic growth combine to make stimulating, though in many parts contentious, reading.

To some extent also, the subsidiary title given above implies more exhaustive treatment than the actual text provides. The emphasis given on the likely opportunities on the Continent to British industry often overlooks the equally great opportunities in the British market for Continental producers. Just as much consideration is required on this other all-important aspect.

These remarks apply especially to the chapter on electrical engineering. It contains some interesting comments on the competitive positions of the European electrical industries, while comparative labour and materials costs and credit facilities are examined. The Report points out that one of the most important aids for electrical manufacturers would be to break down the 'institutional barriers' to British sales on the Continent, but this is easier said than done. The same also applies to the effectiveness of any rules for fair trading, bearing in mind the stringent provisions of our Restrictive Trade Practices Act.

Turning from the Free Trade Area to the Common Market, we should recognize that its political aspects have until recently dominated economic considerations, and the Six Countries are only now coming to grips with these

This book is the first of its kind in Europe, and should be studied by all who are interested in the future of British trade.

F. OLLENDORFF

ELEKTRONIK FREIER RAUMLADUNGEN

VIENNA: SPRINGER-VERLAG. 1957. 620 PP. £8 7S.

This book is the second volume of a large work *Innere Elektronik*. The first was concerned with the electronics of the single electron.* The present volume deals with space-charge phenomena. It starts with a derivation of the Maxwell distribution of velocity in an electron gas, and after a very brief introduction to the subject of electron emission goes on to a most exhaustive treatment of the diode. This is followed by a theory of space-charge guns (Pierce guns, etc.), and space-charge spreading of electron beams. We reach the heart of the book with the theory of the triode. Triode electrostatics is presented in great detail with appeal to Green's function of the triode. The calculation of amplification factor of triodes and multi-grid valves follows. The theory of oscillating space charges starts with the study of the monotron, and continues with velocity modulation and klystrons. Next follow chapters on magnetically controlled space charges, i.e. monomagnetrons, cavity magnetrons, with a very detailed study of cavity modes. Finally, there is a chapter on helical travelling-wave tubes.

* Reviewed in the *Journal*, 1955, **1** (New series), p. 540.

The treatment is mathematical throughout. The author never stops for descriptive or qualitative explanations. Every definition is immediately given quantitatively, and the whole argument is carried out in the form of mathematically formulated questions and answers. The work is very impressive, one might almost say monumental. The presentation is clear and concise, and, with certain exceptions, the mathematics is sufficiently elementary to be followed by a good engineering student. The treatment and presentation are very systematic and original. This is both a strength and a weakness of the work. An exhaustive bibliography is given in which one finds all the papers on the subject one might have read. Yet the book bears very little resemblance to the literature on the subject, particularly where space-charge oscillations are concerned. One wonders how it is possible to write such a large treatise on the subject with so little use of the literature. The answer is found in the nature of the work and in the way it has come to be written. It did not grow out of the needs of a valve laboratory, but out of lectures to students in isolation from practice and often without access to essential confidential literature (for instance Buneman's work on magnetrons could hardly have been known to Professor Ollendorff). As a consequence, the author is more concerned with an academic study of electron motion in valves than with derivation of results which might be important for valve designers. It is greatly to his credit that he has nevertheless produced a work which must be recommended to any serious student of electronic valves. It is not a student's book that could be used instead of Spangenberg's book on electron tubes; nor is it to be consulted for ready formulae and results. They would be hard to find, although they might be there. It is rather a book which a valve engineer might study with benefit to receive inspiration and guidance on how to attack and solve his own problems.

L. F. URWICK

LEADERSHIP IN THE 20TH CENTURY

PITMAN. 1957. 88 PP. 15S.

This is an interesting book of reflections on the quality of leadership, thought provoking and very readable, its urbane style apparently stemming from its source as five lectures given in London at the end of 1955 to 'large audiences of directors and senior executives'. There is a cogent bibliography, an index of scant practical value, and a contents list which details the five chapters: these cover the social necessity of leadership; psychological bases; what the leader does; classic examples; and development. Unhappily, the full discussions stated by the foreword to have followed each lecture are not included. The material is much less regimented than its chapter headings indicate, and the first half of the chapter on what the leader does is a mixture of definitions, notes on democratic election of leaders, and some examples of organizational failures—interesting digressions.

Many important views on the complex threads in leadership are admirably presented, particularly on the sociological and humanity aspects, and on the several paradoxes in the demands on a leader. It is also valuable to read a table of eminent men's views on the most important qualities for a leader.

The reader will be stunned by such sledge-hammer tactics as the three-page quotation from a novel about an air marshal's lack of leadership; and the purist will be worried by confusion between 'educating' and 'training' on p. 83 and by geometrical and mechanical uncertainties in the 'content of management' diagram on p. 7.

Sometimes the author runs straight into a quotation on a subject where one would be just as willing to take his own view, and it may be this preoccupation with backing his own views that leads him to omit some techniques of which he must know and about which the scholar wants to learn. Such an omission occurs on p. 46, where, after summarizing the leader's conflicting problems of sustaining a good administration and of preventing frustration in the undisciplined inventor, he fails to detail any of the known techniques for handling this problem. Again, in disagreeing with a quoted authority on the subject of judgment, he fails to explain the supporting argument. Thus the book rather poses problems than offers solutions, and it shows more zeal in demonstrating the need to train leaders than in offering practical advice.

W. D. WRIGHT

THE MEASUREMENT OF COLOUR

HILGER AND WATTS. 2ND ED. 1958. 263 PP. £2 12S.

This excellent book will be welcomed by all those interested in the measurement of light and colour. The second edition has been almost completely rewritten and considerably expanded, and the high standard expected from the author is well maintained. The volume now deals with: radiation and the eye; the principles of photometry and colorimetry; the 1931 C.I.E. system of colour measurement; colorimeters and spectrophotometers; colour spacing and the colour atlas; colour-mixture data applied to three-colour reproduction; and finally practical applications of colorimetry.

The book has special merit in that it explains the underlying theories very clearly and simply by analogies which will be found particularly useful to those concerned with practical applications. In the sections dealing with instruments the author refers to systems of measurement and visual and physical classes of colorimeters, and includes some instruments of recent design. A more comprehensive account of available instruments would have been useful, but may have been omitted for considerations of space. The subjective aspect of colour is clearly explained, together with the manner in which colorimetry has been used as a tool in the development and study of colour processes. It is useful to find generous reference to the valuable recent work of Stiles on the redetermination of the colour-mixture data and indications of the likely repercussions of this work and its findings in relation to the C.I.E. standard observer, as well as an account of the vision research interest of the work.

In the chapter on the principles of three-colour reproduction the author includes colour photography and printing, and gives an assessment of some of the peculiar problems of colour television, which though brief is up to date and of considerable interest. Professor Wright touches on many practical applications in his final chapter, which thus shows the present-day scope of colour measurement in all its ramifications.

The references are adequate, and the appendices include tables of energy distribution for standard illuminants, and tables of data specifying the standard observer, including weighted distribution coefficients for the standard illuminants and the tristimulus values. These data are extremely useful for practical colour calculations. The book will greatly interest both the student and the advanced practical worker in colour measurement.

Elections and Transfers

The following elections and transfers approved by the Council are effective from the 1st February 1958.

ELECTIONS

Associate Members

BAKER, Alec Edward
CRABTREE, Ian Maxwell, B.E.
DU VAURE, Christian-Marie Buffel
HEWITT, Maurice Charles Paton, B.SC.(ENG.)
HUTCHINSON, Robert, B.SC.
JONES, Gordon
MINISTER, Maior Cyril Nigel Lemoine, B.SC.(ENG.), R.E.M.E.
NUTTALL, Derek
PLIMLEY, Leslie Edward
POPKIEWICZ, Sabin, DIPL.ING.
RAYNAL, Victor Anton, B.SC.(ENG.)
SHELDRAKE, Reshid Pierre Gilbert
SOPER, Sidney James
WILSON, James Frederick, B.SC.
WOOTTON, Geoffrey Buckley

Associates

ANAND, Vidya Bhushan, B.A., M.SC.
BAVERSTOCK, Alfred Luther Reginald
FERGUSON, Hugh
THOMPSON, Joseph Geoffrey
WELTON, David George

TRANSFERS

Associate Member to Member

AHMAD, Zaki Uddin, B.SC., PH.D.(ENG.)
ANKETELL, Cecil Augustus Ratnasingham, B.SC., B.SC.(ENG.)
DESHPANDE, Prof. Murlidhar Vinayak, B.E., M.S.
EVANS, Frederick William
HAMILTON, James, M.ENG.
HEYS, Cyril
HOWE, Alfred Bernard, O.B.E., M.SC.
JAMIESON, William, B.SC.
LAKHANPAL, Dev Datta, B.A., B.SC.TECH.
MORGAN, Lt.-Col. William Clifford, B.A.
REEVES, Leslie Norman
SCARBOROUGH, Walter Howard, O.B.E.
WATSON, John Frederick
WOOD, Herbert Brian, B.SC.

Associate to Associate Member

INTERLOFF, Thomas

Graduate to Associate Member

ABBOTT, Jack
ANDREWS, Anthony
BALL, Maurice Alvey, B.SC.(ENG.)
BICHTLER, Maurice Arthur Edward, DIPL.ING.
BENNETT, James Rome
BHATT, Premanand Janardhan, B.SC.(ENG.)
CHARLTON, Willis
CHRISTMAS, Walter Silvester
CLARK, Walter Edward
COCKBURN, Andrew Stoddart
CRAWFORD, William Jollie
CROW, Denis Edward, B.SC.(ENG.)
DAVIES, Beaumont John, B.SC.(ENG.)
DAVIES, Stanley, B.SC.(ENG.)
DRAYSON, Michael, B.SC.TECH.
EAST, George Douglas
ELLIOTT, Richard Westcombe
ELLIS, Edwin Jack
EVA, Frederick Norbury
FENSOME, Frank
FORD, James, B.SC.(ENG.)
FUGILL, Cyril Brian, B.SC.(ENG.)
GOODWIN, John Edward, PH.D., B.SC.
GREGORY, Alan Robert, B.SC.(ENG.)
HARBOTTLE, James Reginald, B.SC.(ENG.)
HARRIS, John Granger
HAWKES, Herbert Geoffrey, M.A.
HAYCOCK, Norman Frederick
HOWORTH, Jack Raymond, B.SC.(ENG.)
INGRAM-COTTON, Capt. John Bruce, R.E.M.E.
INNES, Edgar
JENKINS, William Henry
JOYCE, Harold Reginald
LEONARD, John Herbert
LITTLER, Graham Esmonde
MCNEILLIS, George Joseph
MCVEY, Capt. Peter James Wailey, B.A., R.SIGNALS
MALLINSON, John Neville Gardiner, B.SC.
MEAD, Dennis Arthur Alfred
MEDFORD, Reginald Derek, B.SC.(ENG.), M.SC.
MILLER, Ian Robert Gray, B.SC.
NEWELL, Frank Peter, B.SC.(ENG.)
OUTTEN, Albert Edward
OWEN, Herbert Frederick
PETRY, Thomas Joseph
RIMMER, Albert Royston, B.SC.TECH.
ROBERTS, William Joseph, B.SC.(ENG.)
ROSTRON, James Philip, B.SC.(ENG.)
SANDERS, Anthony Leonard, B.SC.(ENG.)
SAUNDERS, Ronald George
STOCK, Peter John
SWAN, James William, B.SC.(ENG.)
SYKES, Brian Frank
SZUMSKI, Henryk
TULEY, James Harold, B.SC.(ENG.)
VARUGHESE, Jacob Mangatt, B.A. M.SC.TECH.
WILSON, Lt.-Cmdr. Kenneth Stanley, B.SC.(ENG.), R.N.
WOODINGTON, Derek John, B.SC.(ENG.)

Student to Associate Member

CORBETT, Ronald Irvine

The following elections and transfers approved by the Council are effective from the 6th February 1958.

ELECTIONS

Graduates

AINSCOW, Philip Watson
ALLCORN, John Arthur
ALLIN, Gordon
ANDERSON, Thomas
ATTER, Derek
BAIN, Derek Stanley
BAINBRIDGE, Philip Frederick
BEAMENT, Stanley Frank
BELL, William Robson, B.SC.
BIDGOOD, John Frederick Simon, B.SC.(ENG.)
BIRCH, Alan Keith
BOSMAN, Anthony Peter
BRACEY, Michael Frederick, B.ENG.
BROWN, Edward Lewis
BROWN, James
BUNDAY, Derek Cecil
BUNDEY, Derek Alan
CARVALHO, Frederick Leonard
CHALMERS, Peter Michael, B.ENG.
CHAMBERS, Ronald
CHENOWETH, Charles Philip Ernest, B.E.E.
COATES, Russell
CORNER, Eric
COSSER, Harry Frederick, B.SC.
CRAMPHORN, Ralph Howard
CRUMPEN, Mervyn James
CURLE, James
CUSACK, George Joseph
DANIELS, Brian Anthony
DAVIES, Eric Hywel Royston
DAVIES, Roy Patrick
DAWSON, John Thomas
DEVONALD, Sydney George
DUNN, Robert Brian
ELKIN, Brian Frederick
ELLWOOD, Ernest
EMERSON, Sidney Edward
EVANS, Arthur
FARRELL, Thomas Henry
FEWSON, Denis
FISHER, Gordon William
FORD, Norman William
FORSKITT, John Charles
FOX, Gerald William Hardy
FULTON, Mark, B.E.
GHOSE, Amal Chandra, B.SC., B.ENG.
GILL, Thomas Henry
GIRVIN, Gordon Victor
GLEW, Dennis Alfred
GREAVES, Joseph
GREENHILL, Lawson
GREENLEES, Walter
GRONOW, William Stanley
HALL, Brian Reginald
HAMONO, Alan Barry, B.E.
HEATH, Peter Bryan
HIRST, George Gerald
HOBBS, Raymond George Gilbert
HOLLOWAY, Stanley
HOLROYD, John Arthur, M.A.
HUMPHRIES, William Gerald
HURST, Ronald
HYPHER, Bernard Ignatius
JACKMAN, Walter William
JENNINGS, Barry Michael
JENNINGS, Robert
JOHNSTONE, John Perrin
JONES, Wyndham Ivor
KENSHOLE, Lt. Hugh Harding, B.A., R.N.
KENWAY, Rex George Clifford
KHAN, Abdul Wadud
KNIGHT, Reginald Arthur
LEWIS, John Roger
LLOYD, David Broome, B.SC.(ENG.)
LOBB, Anthony Bernard Cyril
LUCK, John Edward
MACLEAN, Donald
MCLEOD, Roderick Cyril
MAINGOT, Martin Anthony
MAZEY, Derek William
MERCER, Pilot Officer Michael John Profit Hallahan, R.A.F.
MUKHI, Lajpat Mangharam, B.SC., B.SC.(ENG.)
MUNROE, Ernest Frederick
NOBLE, Colin Douglas
NUTTALL, Albert
OATEY, Alan Henry
OLOWU, Olayeni, B.SC.(ENG.)
OTTER, Bryan Patrick
OWEN, Robert David
PAGE, Ernest Thomas, B.E.
PAIN, Frederick John
PHILIPS, George Kanianthra Oommen
PHILLIPS, Kevin John Arthur
PIERCEY, Deryck Clive, M.SC.
PINNOCK, Desmond Cecil
POWELL, Alan John
POYNTER, Roger Charles
PRICE, Jack Richard
PROFFITT, Donald
PRYCE, John Edwin
PYM, Roy Samuel
RAJAGOPAL, Ramasamy, B.SC.(ENG.)
RALPHS, David
RAWLINGS, Eric Joseph
REEVES, Malcolm
ROGAN, Bernard
SARKAR, Goutam
SCARBOROUGH, Francis Arthur
SCRIVENER, David Hayter
SEAGER, Ronald William
SHARP, Peter James
SHELTON, Anthony Norman
SIMM, James Henry
SIMMEN, William Douglas
SIMPSON, Arnold
SINCLAIR, William John, B.E.
SIWKO, Karol, B.SC.
SKERTCHLEY, Paul Neville
SLANEY, Jeffrey
SNOWLING, Alan
SPITTLE, Walter
STAFFORD, Edward Michael, B.SC.
STRIVENS, David John
TAYLOR, Frank
TEALE, Vernon John
TOFT, John Gordon
TOPLIS, David John
TUMBER, Terence Simeon George
TURNER, Allan
URBAN, Charles Edward
VASEY, Joseph Ronald
WALKER, Gerard
WALLER, Ian
WARBURTON, David Eric
WARRICK, Patrick Kay
WEARING, Frederick Sydney
WEBSTER, Gordon Fenton
WENT, Jack Downes
WHITE, David James
WIGGANS, Michael Thurston Richard
WOOBERRY, David Edward
WOOLMINGTON, Allan

Students

ABBOTT, Warwick Reginald
ALDRIDGE, Basil John Clive
ALLAN, Anthony Gavin
APPLE, Dennis, B.SC.
ASHWORTH, John Reginald Howell
ATTERBURY, Gerald Frederick
BANSAL, Rajinder Kumar, B.A.
BEGGS, Bruce James
BERRIDGE, Anthony Edward
BIGGINS, George Edward
BISHOP, Michael John
BODY, David Henry John
BRIDGEMAN, Roger Geoffrey
BROOKS, Barrie John
BROWN, Clive Greenaway
BROWN, Peter

Students (contd.)

BROWN, Peter Kenneth
BURGOYNE, David Michael
BURKE, Terence Frederick James
CHALK, John Edwin George
CHARD, John Anthony
CHAUDHRY, Sushil Prakash, B.SC.(ENG.)
CHILCOTT, Benjamin Cardew
CLARKE, Gerald Sydney
CLEWS, Brian Leslie John
CLOUGH, Geoffrey Eric
COLLINS, Brian Arthur
CONNOR, Patrick Michael
COVEY-CRUMP, David John
CRAIG, James Cameron
DALGLISH, David Philip
DAVIES, Colin Howell
DEAKIN, Barry
DEVENISH, Neville George
DEWHURST, Geoffrey, B.SC.
DOUGLASS, Alexander Mark
DUCAT, Roger Leslie
EDWARDS, Geoffrey David
EDWARDS, Phillip James Walton
ELLIS, Tom
ERITH, Geoffrey
FERRETT, Neil Antony, B.SC.
FIELD, Robert James
FISHWICK, Roger Oliver
FOORD, Kenneth John
FORSTER, Graham Arthur
FRANKLIN, Philip James
FREER, Colin George Harry
FROST, Peter Frank
FRY, Bryan Edwin Thomas
GAME, John Frank
GARD, Alan Edward Norman, B.SC.
GARRETT, John Arthur
GATLEY, John Andrew, B.SC.(ENG.)
GENT, Alan Edwards
GOODING, Patrick Michael
GORDON, Alfred Henry
GORROD, Peter John Brebner
GOSLING, John Buxton
GOVINDARAJAH, Ratnasamy
GRAY, John Oliver
GRIFFITHS, Edward Roy
GYAW, San Tun
HADDON, Ernest Trevor
HALES, Stuart de Warren
HANCOCK, Roger Martin
HART, Geoffrey Terence
HILL, John Michael Hughes
HITCHEN, Grahame Barrington
HODGKINS, John Arthur
HØEG, Tor-Andreas
HOLMES, John Wetherfield Harold
HUGHES, John Barry
HUNTER, Robert Derrick McIntosh
HUTCHERSON, Peter, B.SC.
JACOB, Alexander Frederick
JARVIS, William Anthony
JENKINS, Gerald Walter, B.A.
JENKINS, Peter Howell
JOLLEY, William Peter
KULENDRAN, Thampoe
KWOK, Ping-Ki
LAKE, Malcolm Winfield
LAMB, Eric Thomas
LAMPTEY, George Benjamin
LANG, James
LEE, John Leslie
LEESON, John Chetwode
LIDSTONE, Stanley Richard Charles
LIGHTBURN, Peter John
LING, David Michael
LORD, William
LYNCH-WATSON, David
MCCONNELL, Peter Orman
MACPHERSON, Timothy Ian
MEHTA, Pravin Chandra
MILLER, Thomas Ernest Frarey
MILTON, David
MORRIS, Clive John
MORRIS, Michael William
MURTHY, Surapaneni Radha Krishna
MYNOTT, Peter Hall
NASH, Michael Fraser
NYUNT, Kyaw
PATERSON, Donald Augustus
PATHAN, Mujibdadkhan Habibdadkhan, B.SC.
PATTERSON, Iain Martin Munro
PAYLOR, David Marsden
PEARSON, John Douglas
PERCIVAL, Barrie Spencer
PETERSEN, Robert Laurance, B.SC.
PHILIP, Robert Finlay
PHILLIPS, David William
PIROOZ, Jamshid
PISANI, Lawrence
POWER, Donald George
PRICE, Thomas Edward
PUPLAMPU, Alexander Buertey
REID, Robert
RENDLE, Richard Garth
REW, Ian Arthur
RUMNEY, Henry
RYLEY, Derek Vernon
RYLEY, John Edwin
SANCHEZ, Fernando Juan
SANDFORD, John
SANSOM, Colin Albert
SARGENT, Keith Valentine
SARKAR, Subrata Kumar, B.SC.
SELLINGS, Richard Barrington, B.SC.(ENG.)
SEVERY, Brian John
SHENTON, Raymond George
SHEPPARD, John
SIMPSON, Arthur
SLIGH, Alastair David Moffat
SMITH, John
SMITH, Peter
TAYLOR, James Stephen
TEMPLAR, David Edmund, B.SC.
THOMAS, John Stuart
THOMPSON, Gordon
TODD, Peter
TRUMAN, John David
URQUHART, Alexander John
VICKERS, Harry
WANG, Daniel Hung-Yue
WARNER, Philip Barry
WATSON, David Lancaster, B.SC.
WESTON, David Brian
WHITWORTH, Robert Edward
WILKINS, John Alan
WILSHER, Kenneth Reginald Walter William
WOOD, Peter John

TRANSFERS

Student to Graduate

AGARWAL, Harsh Kumar, B.SC.(ENG.)
BATES, John
BELL, Hugh Arthur, B.ENG.
BENSON, Francis Gordon, B.ENG.
BINNING, George, B.SC.
BOOTH, Harvey James
BURGESS, Peter William Ewan
BURROWS, Philip John
CLARK, Arthur John Sydney
CROSSLAND, Bernard, B.SC.(ENG.)
DAVEY, John Charles, B.SC.
DAVIDSON, James Smyth
DAWE, Geoffrey, B.SC.
DIXON, James Maurice
DREWE, Dennis John William, B.SC.
DUCKER, Francis Ronald
GARRATT, Derek Herbert, B.SC.(ENG.)
GHOSHAL, Benode Gopal
GRAY, Gordon
HAMMONS, Thomas James, B.SC.(ENG.)
HARLE, Alan
HARPER, Peter Anthony
HARRIS, David Tom
HODGE, Brinsley John Rowan, B.SC.(ENG.)
HOLLIDAY, Michael John, B.SC.(ENG.)
HUXLEY, Raymond Peter
JOLLY, Michael Eliot, B.SC.
JONES, Leonard James
KEARNEY, Peter Clement
KHAYATA, Mohamed Nouri, B.SC.(ENG.)
LEIGHTON, John Owen

Student to Graduate (contd.)

LEWIS, David William
MCCLEAN, Robert
MCCLURG, James Alexander
MACPHERSON, Robert Blackburn, B.SC.
MANNING, Victor Royston
MASON, Christopher James Woodville
MEDCALF, Gordon Edward, B.SC.(ENG.)
MEHTA, Jayantilal
NORTH, Eric Frank
NYE, Peter James
ONSLOW, Dennis
PARSONS, David Ernest William
PARSONS, David John, B.SC.(ENG.)
PEARS, George Arthur, B.SC.(ENG.)
RICHMAN, Bruce Lionel
ROBERTS, David Richard, B.SC.
ROBSON, Colling Frank
ROWE, John Howard
SADDLETON, George Ernest
SAKSENA, Shrawan Kumar
SAMAD, Sub.-Lt. Mohammed Abdul, P.N.
SHARMAN, Ernest Keith, B.SC.(ENG.)
SMITH, Alan Raymond Kenneth
SOAMES, David Spencer
SPENCER, Neil Rewbridge, B.SC.(ENG.)
STATHERS, Eric
STAWELL, Lt.-Cmdr. William Bowring, R.N.
TAYLOR-CUMMINGS, Denis Edward
TRICKER, Anthony John
TYM, Aubrey James William, B.SC.
WALKER, Peter James
WATTS, Peter
WELLING, Peter Francis, B.SC.(ENG.)
WILLIAMS, Mervyn John
WILLIAMS, Roger
WOLSTENHOLME, Peter, M.SC.
WOOD, Peter
WOODWARD-NUTT, Peter James, B.SC.(ENG.)
YOUNGS, Fountain Charles Lockwood, B.SC.

The following elections and transfers approved by the Council are effective from the 1st March 1958.

ELECTIONS

Associate Members

DUCKWORTH, Jack
EARDLEY, Donald Ernest, B.SC.
FULLER, Louis, B.SC.(ENG.)
GOLDEN, Norman Jerome, S.B.
HARMAN, Reginald Richard
HEWETT, Norman Basil, B.SC.
INESON, William James Lawson, B.SC.
JOLLY, William Percy, B.SC.
KIRYLUK, Wlodzimierz
REEVES, Lt.-Comdr. Paul Anthony Thomas, B.SC., R.N.
SUNDERLAND, Ronald Frederick
SZYMANOWSKI, Jaroslav
THOMASON, James Gordon, B.SC.
TILBROOK, Capt. Frederick Herbert
WELSH, Alexander Wright
YOUNG, David Gray, B.E.

Associates

DE ZOYSA, Eustace Walter
EVANS, Richard
KITCHENER, George Gilbert
SHIRLEY, Arthur Baxter
VERNIER, Charles Leonard Patrick
WILLIAMS, Frank

TRANSFERS

Associate Member to Member

BATEMAN, Wilfrid, M.A.
BLACK, Lawrence Henry, B.SC.(ENG.)
COOK, Thomas Henry, B.SC.(ENG.)
JOHNSON, Guy Winter, B.SC.(ENG.)
LYON, George, M.SC.(ENG.)
MARRIOTT, Harry, B.ENG.
NEWMAN, Percy Laurence, T.D.
PARTRIDGE, Thomas Henry
RICKS, Bertie William
SYKES, John Herbert
WAGSTAFF, John Harwood, B.SC.(ENG.)

Associate to Associate Member

HERRIOTT, Albert Edward
KARVE, Govind Vishnu, M.SC.
KENWORTHY, Lt.-Col. Ernest Wild, R.E.
REECE, Percy Cairns

Graduate to Associate Member

AMIN, Mohammad, M.A.
BASHAM, Brian, B.SC.(ENG.)
BEACH, Francis, B.SC.(ENG.)
BERESFORD, Wilfred Lawrence
BONIFACE, Santia, B.SC.(ENG.)
BRINKWORTH, Eric Reginald William
BROWNE, Lorimer Carlyle, B.SC.(ENG.), PH.D.
BURGESS, John Anthony
CARRADICE, George Lewthwaite
CLARK, Donald Anderson Wemyss, B.SC.(ENG.)
COLES, Peter Kenneth
COLLINS, Eric Godwin
CUTTS, Frederick Arthur
DELLA PORTA, Joseph Harry, B.SC.(ENG.)
DENNETT, Cedric Roger Leighton, B.SC.TECH.
DICK, David
DONALDSON, John McGregor, B.SC.
DRAKE, John Alfred
DRINKWATER, Bryan John
ELDER, Hugh, B.E.
ELLIOTT, William Roper
ELLISON, James Bruce
ETHERINGTON, Mrs. Dorothy
FOSTER, Fergus Blackwell
GIFFORD, William Roy
GRUNFELD, Paul
GUNAWARDENA, Hettipathirannehelage Don Sirisena Arthenayake, B.SC.
HALL, John Charles William
HARRIS, Thomas Raymond
HAYWARD, Brian Frank Wilson
HOLME, Alfred Ernest Tughan
HUTTEN, Peter Robert Henry, B.SC.(ENG.)
IMRIE, James Wilson
JARRETT, John James
JONES, Eric
KENDON, Richard Donald, M.A.
KING, Alexander Charles
LATHAM, George Alexander
LAURENCE, Robert
LEE, Ronald James, B.SC.(ENG.)

Graduate to Associate Member (contd.)

ROEBUCK, George Victor
SANYAL, Gitindra Saran, M.SC.
SHARPE, Edgar Herbert Hand
SMITH, Alan
SNEAD, Albert Edward
STALLWORTHY, Berwick Vyse, M.A.
STEPNIEWSKI, Bolesław
WALDRON, William Bernard
WARING, Richard Hugh, B.SC.
WARNER, Roy Maybury
WHEELER, Peter Reginald
WHITAKER, James Douglas, B.ENG.
ZIMMERMAN, Reginald Guy Drew

Student to Associate Member

LEWIS, John, B.SC.

The following elections and transfers approved by the Council are effective from the 6th March 1958.

ELECTIONS

Graduates

KOSSATZ, Christoffel Petrus, B.SC.(ENG.)
LASHFORD, Michael Thomas
LOMAX, John Anthony
LOOSLEY, Peter John
MCLELLAN, Peter George
MAINPRIZE, Gerald Harry
MAY, Anthony Julian Charles
MENDELSON, Jack
MORIARTY, Dermot Kevin
NATH, Narinder, B.E.E.
NAYLOR, Kenneth John
NEIL, Graham James, B.SC.(ENG.)
NETHERSOLE, Michael John
NOBLE, Gordon Frank
OAKLEY, Graham Southall
O'DWYER, Martin Gerard
OKORO, Matthias, B.SC.(ENG.)
OLAUSSEN, Leif Kare, B.SC.(ENG.)
OLIVER, William Ernest
PAGE, William
PEACH, Frederick Sidney
PETERSEN, Marinus Robert George
PROUDLER, Dennis Hall, B.SC.TECH.
QUELCH, John Weston, B.SC.
ROBERTS, Alan George Frederick
SAGE, Peter Kennedy
SANDBANK, Carl Peter, B.SC.
SAUNDERS, Pilot Officer David Murray Nathaniel, R.A.F.
SEYMOUR, George Ramage, B.SC., B.E.
STARTIN, Richard Clive
STOKES, Frank Stanley
STOKOE, Edward
STYLES, Alan Roland
SWEETMORE, Reginald George
TARNER, Henry Charles James
TIPPING, William John Brian
TRUMPER, Derek Albert
UTTERIDGE, Derek Donald
WARD, William Edward
WARREN, Keith Edward
WATSON, Raymond Norman
WEIR, Alexander Tait, B.SC.
WILKINSON, Frederick
WILLIAMS, Robert Glynne
WOOD, Henry, B.SC.(ENG.)
WORRALL, William Herbert
YOUNG, John Alexander
YOUNG, Kenneth Moir, M.A.

Students

BLY, Dennis William John
BOURNE, John Edward
BRADSHAW, Stanley Leslie
BROWN, William
BRYANT, Alan John
BRYCE, Andrew Bonner
BURCOMBE, John Edward
BURTWELL, Peter Lavender
CAVE, Gordon Russell, B.A.
CHEESEMAN, Roy Lawrence, B.SC
CLERK, Atul Vaikunthlal

Students (contd.)

COLE, David Benjamin
COLLING, John Anthony, B.SC.TECH.
COLLINS, Gerald
COOK, Graham Arthur, B.SC.
COOPER, Brian Ralph
CURRY, Robert George
D'AGUILAR, Vincent Yelverton
DARLASTON, Keith Darrell Edward
DAVIES, Dilwyn, B.SC.
DAWSON, Michael John Groombridge
DICKENS, Robert York
EADES, John David
FORSTER, John
FUNG, Norman
GARDNER, Michael George
GILL, Norman John
GILLIS, Ian James
GRESHAM, Robert James
HALL, Brian
HALLETT, David Norman
HARDY, Brian John
HARRIS, John Cecil
HARVEY, Nigel Paul, B.SC.
HEATH, John
HENZELL, Joshua Edward
HOLDEN, George Colin
HOWES, Kenneth Moir
HOYLE, John Malcolm, B.SC.
HUNTER, William Stuart
INSHAW, Michael William
JARRETT, Gerald
JOHNSON, Colin Peter
JOHNSON, Michael Robert
JOHNSTON, James Neill
JONES, Malcolm Harvey
JONES, Nicholas
JONES, Peter Lumsden
KELSEY, Gordon Richard
KIIL, Bjarne
KING, Philip William
LAST, Brian Patrick
LAWSON, Robert Keith
LEAN, Chin Keat
LEAVEY, Denis Ernest
LLOYD, Denis George, B.A.
MACLACHLAN, Norman William
MANN, Ernest George
MARRISON, John Hedley
MARTIN, Denis Norman
MEACHER, Edward Charles
MILLER, Ian
MILNE, John
MOFFETT, Austin
MORGAN, Alan Thomas
MORLEY, Derek, B.SC.
NAKKASHA, Hikmat
NORRIS, Bryan Leslie
OLDFIELD, Brian
PATEL, Chandrakant Motibhai
POWELL, Reginald
PUNSHI, Romesh Chander, B.A.
PUTTICK, Arthur David John, B.SC.
REED, Ronald William
REYNOLDS, Anthony Charles, B.SC.
ROBINSON, Peter Graham Philip
RYDER, David John
SAVAGE, John Baird
SCRUTTON, William Henry Charles
SHEARD, Maurice
SMITH, Frank Bernard
SOLEY, Miss Barbara Joan
STILLING, John William
STOKOE, David John
STUBBS, Michael John
TAYLOR, Derek
THOMAS, Owen Beynon
TUCK, David William
TYLER, Brian
UMPELBY, Anthony Michael
UNDERWOOD, Brian William
VERNON, Roy Marshall
WELLARD, Terence Charles
WHITTAKER, Barry Stuart, B.SC.
WILKES, Anthony James
WILL, Alexander James
WILSON, Martin Roderic, B.SC.(ENG.)
WISHART, Keith
WOOD, Alan Ronald
YONG, Chin Tong
YOUNG, Edward John

TRANSFERS

Student to Graduate

APPLEBAUM, Martin
BOLTON, Francis
BOLTON, Peter Charles
BORCHERDS, Peter Howard, B.SC.
BRADBURY, Ralph Anthony
CABLE, John
CASELEY, Thomas Ewart Bater
CLARKSON, Alan, B.SC.
CLINCH, Donald William Lister
CREAK, Richard Adrian, B.SC.
DAVIES, Donald, B.SC.
DAVIS, Douglas Gerald, B.SC., PH.D.
ENDERSBY, Derek Colin, B.SC.(ENG.)
FLINT, Anthony Michael, B.SC.
FULLWOOD, Kenneth John, B.SC.(ENG.)
GARBUTT, Eric Ernest
GIBSON, Alfred
GILBERT, John Barrie
GUEST, Simon Gavin, B.SC.(ENG.)
HANKINSON, Lewis Peter
HARDY, David Heugh, B.SC.(ENG.)
HAWKINS, Fl.-Officer James William John, R.A.F.
HOPE, John Alan
JACKSON, George Alan
KELEHER, Colin Raymond
KNOWLES, James Brian, B.SC.TECH.
MACPHERSON, Colin, B.SC.(ENG.)
POWELL, Bernard George
QUILLIAM, Barrie, B.SC.
RADFORD, Anthony Joseph, B.E.
REUTENS, Adrian Marie
RICHARDSON, Clive Edward, B.SC.(ENG.)
ROULSTON, David John, B.SC.
ROUTLEDGE, Donald Malcolm
SANDERS, Michael Whitaker
SEAGER, Arthur Ernest, B.SC.(ENG.)
SHARMA, Ram Kumar, B.A., B.SC.
SHAW, Fred, B.SC.
SHENTON, Colin George Arthur
SIERS, Ernest Frederick
SLOAN, John Allan
SMALLWOOD, Roy Frederick
STOCKFORD, Roger Kenneth
WALSHAW, Michael Harland, B.SC.(ENG.)
WARD, Brian William, B.SC.(ENG.)
WARRILOW, Paul
WEDGE, Marcus, B.SC.(ENG.)
WEST, Robert John
WHYTE, Ian Arthur
WILD, Peter
WINTERBOTTOM, Norman, B.SC.
WONG, Donald Che Kwan

AUTO-SUGGESTION?

'Experience suggests that few, if any, books manage to reach their first edition without some errors. This volume is hardly likely to be the exception. . . .'

From the preface of a recently published book written by a member of The Institution.

LIBRARY ACCESSIONS

**Denotes that the publication is also in the Lending Library. The publications cannot be brought through The Institution; the publishers and the prices are given only for the convenience of members.*

MARTON, L. (Editor) 621.38

Advances in Electronics and Electron Physics Vol. IX*

New York, Academic Press, 1957. pp. x, 347. 23 × 15 cm. £3 12s.

Contains a number of papers by British and American authors on electronic techniques in geophysical exploration.

RAPSON, E. T. A. 621.396

Problems in Radio Engineering. 7th ed.*

London, Pitman, 1957. pp. vi, 177. 19 × 13 cm. 15s.

Problems from past City and Guilds papers in radiocommunication, The Institution's examination in electrical communication and London University papers. The M.K.S. system of units is used.

REYNER, J. H. 621.317.755

Cathode-Ray Oscillographs. 5th ed.*

London, Pitman, 1957. pp. ix, 206. 19 × 13 cm. 20s.

A simple guide to the use of the cathode-ray tube for examining waveforms, as a measuring instrument and for many other purposes.

SHOTTON, A. C. 621.3 (076)

Worked Examples in Electrotechnology. (M.K.S. Units) With Graded Exercises

London, Harrap, 1957. pp. 240. 20 × 14 cm. 12s. 6d.

Presents carefully detailed solutions to selected problems and also problems for the student to solve, chosen from the examination papers of a number of organizations.

SKEAT, W. O. 93:01

King's College London Engineering Society 1847–1957

London, King's College, 1957. pp. 119. 22 × 14 cm. Private circulation.

WYLLIE, M. R. J. 550.83

The Fundamentals of Electric Log Interpretation

New York, Academic Press, 1957. pp. x, 176. 21 × 13 cm. 36s.

A practical description of methods of measuring soil resistivity and analysing the results to determine the nature of the soil or rock and the presence of oil or gas pockets.

Forthcoming Events at Savoy Place

All meetings are held at Savoy Place, beginning at 5.30 p.m. (tea at 5 p.m.), except where otherwise stated. The nature of the meeting is indicated by the following key:

E EDUCATION DISCUSSION CIRCLE
I INFORMAL
M MEASUREMENT AND CONTROL SECTION
O ORDINARY
R RADIO AND TELECOMMUNICATION SECTION
S SUPPLY SECTION
U UTILIZATION SECTION

After each paper that has now been published is added the month that a synopsis has appeared in the *Journal* under 'Monographs and Papers published individually this month', i.e. about the time the paper has been published as a separate. A paper that has not yet been published will be available at least ten days before the meeting at which it will be read.

April 1958

S **16** *Wednesday* (In conjunction with the British Nuclear Energy Conference) K. L. STRETCH, M.A. 'Operational Experience at Calder Hall' (Paper No. 2594 s) *Synopsis:* see p. 205

U **17** *Thursday* R. F. BURBIDGE, B.SC. '2/1 Pole-Changing Motors'‡

R. S. WIGNALL, B.SC. 'Project Considerations for Diesel-Electric Traction'‡

A. WREN 'Some Applications of Mercury-Arc Rectifiers'‡

R **23** *Wednesday* D. E. L. SHORTER, B.SC.(ENG.) 'Survey of Performance Criteria and Design Considerations in High-Quality Monitoring Loudspeakers' (Paper No. 2604 R) *Synopsis:* see p. 205

O **24** *Thursday* H. V. PUGH 'The Generation of Electricity in the London Area' (Paper No. 2445 s) *Synopsis:* November 1957

R **28** *Monday* Informal Evening on 'Economic Usage of Broad-Band Transmission Systems' at which there will be a talk given by R. J. HALSEY, C.M.G., B.SC.(ENG.)†

MS **29** *Tuesday* J. N. PREWETT, M.A. 'A Method of Measuring and Displaying Generator Rotor Angle' (Paper No. 2602 M) *Synopsis:* see p. 205

E. B. POWELL *and* M. E. HARPER 'Generator Rotor-Angle Measurement by Stroboscopic Means' (Paper No. 2576 M) *Synopsis:* see p. 205

F. MORAN, M.SC. 'Power-System Phase-Angle Measurements' (Paper No. 2598 s) *Synopsis:* see p. 205

S **30** *Wednesday* F. C. WINFIELD, M.ENG., T. W. WILCOX *and* G. LYON, M.SC.(ENG.) 'The Design of the 330 kV Transmission System for Rhodesia' (Paper No. 2583 s) *Synopsis:* see p. 205

May

M **6** *Tuesday* A. T. STARR, M.A., PH.D., B.SC. Lecture on 'Some Case Histories of Business Computers in the U.S.A.'‡

U **8** *Thursday* P. T. STANDRING, PH.D., B.SC. Lecture on 'Artificial Fibres'‡

E **9** *Friday* G. MATHER, B.SC.TECH. will open a discussion on 'The Teaching of Applied Acoustics'* (At 6 p.m., tea at 5.30 p.m.)

R 14 *Wednesday* D. GABOR, DR.ING., F.R.S., P. R. STUART *and* P. G. KALMAN 'A New Cathode-Ray Tube for Monochrome and Colour Television' (Paper No. 2661 R) *Synopsis:* see p. 206

15 *Thursday* ANNUAL GENERAL MEETING *followed by* D. G. FINK Lecture on 'Recent Developments in Electronics in the United States'‡ (At approximately 6.30 p.m.)

U 16–18 *Friday–Sunday* Section Visit to Porthcawl

R 19–23 *Monday–Friday* International Convention on Microwave Valves (Full details and registration form obtainable from the Secretary)

S 28 *Wednesday* P. F. GUNNING 'Standardization of Control Facilities for the British Grid Communications, Indications and Telemetering' (Paper No. 2626 s)

G. A. BURNS, F. FLETCHER, C. H. CHAMBERS *and* P. F. GUNNING 'The Development of Communication, Indication and Telemetering Equipment for the British Grid' (Paper No. 2627 s)

S 31 *Saturday* Section Visit to Leatherhead

June

M 7 *Saturday* Section Visit to B.B.C. Television Studio and Electricity Council Training Establishment

25 *Wednesday* Institution Conversazione at the Royal Festival Hall, at 7.30 p.m.

* No advance information will be available and no Press report will be permitted.
† An abstract will be available in advance.
‡ No advance information will be available.

British Nuclear Energy Conference: Forthcoming Programme

MAY 1 *Thursday*

Sponsoring society: The Institute of Metals.

Place of meetings: Church House, Westminster, London, S.W.1. Tickets will not be required.

10.0 a.m.

Informal discussion on THE LIFE OF FUEL ELEMENTS

No advance copies of papers are being issued.

2.30 p.m.

SYMPOSIUM ON PLUTONIUM AND METHODS OF HANDLING IT

A HISTORY OF THE EARLY BRITISH WORK ON PLUTONIUM METALLURGY

Professor J. G. Ball and W. B. H. Lord

SOME FACILITIES FOR THE STUDY OF PLUTONIUM AND ITS ALLOYS

G. K. Williamson, D. M. Poole and J. A. C. Marples

TECHNIQUES FOR THE STUDY OF PLUTONIUM METAL

W. B. H. Lord and M. B. Waldron

THE PLUTONIUM-IRON SYSTEM

P. G. Mardon, H. R. Haines, J. H. Pearce and M. B. Waldron

A PRELIMINARY INVESTIGATION OF THE PLUTONIUM-THORIUM SYSTEM

D. M. Poole, G. K. Williamson and J. A. C. Marples

SOME INVESTIGATIONS ON PLUTONIUM METAL

E. Dempsey and A. E. Kay

All six papers will be printed in *The Journal of the Institute of Metals* before the date of symposium.

Contents of the Current Issues of the *Proceedings*

The date in italics is that of the Journal review or special article. Where given, the date in capitals refers to the month in which a paper was published individually.

PART A. POWER ENGINEERING (APRIL 1958)

Discussion on **Age and the Incidence of Fires in Electrical Installations** before the Southern Centre, the South Midland Supply and Utilization Group, the Northern Ireland Centre and the South-Western Sub-Centre

L. ABRAM, B.SC.(ENG.), J. P. MCBREEN, AND J. SHERLOCK, B.SC.(ENG.). PAPER NO. 2324 U, FEBRUARY 1957

D.C. Winder Drives using Mercury-Arc Rectifier/Inverters *March 1958*

H. A. P. CADDELL, M.A.

North Staffordshire Sub-Centre: Abstract of Chairman's Address

F. MATHER. PAPER NO. 2420 S, OCTOBER 1957

Earthing of Low- and Medium-Voltage Distribution Systems and Equipment *April 1958*

F. P. BENTHAM. PAPER NO. 2424 U, NOVEMBER 1957

Electric Control of Stage and Television Lighting *March 1958*

W. A. SHARPLEY AND J. V. OLDFIELD, B.SC.(ENG.). PAPER NO. 2404 S, AUGUST 1957

The Digital Computer Applied to the Design of Large Power Transformers *April 1958*

E. D. TAYLOR, M.SC., B. BERGER, B.SC.(ENG.), AND B. E. WESTERN, B.SC. PAPER NO. 2505 S

An Experimental Approach to the Cooling of Transfer Coils by Natural Convection *Not yet reviewed*

H. E. J. SYMES, M.SC.(ENG.). PAPER NO. 2556 U

The Principal Characteristics and General Analysis of a New Epicyclic Drive for Electric Locomotives *April 1958*

R. L. RUSSELL, M.SC., AND K. H. NORSWORTHY, B.SC. PAPER NO. 2525 U

Eddy Currents and Wall Losses in Screened-Rotor Induction Motors *April 1958*

G. W. BOWDLER, B.SC. PAPER NO. 2543 M

The Measurement of High Voltages with Indicating or Recording Instruments *March 1958*

PART B. RADIO AND ELECTRONIC ENGINEERING (MARCH 1958)

See the Journal for March 1958, p. 158.

PART C. MONOGRAPHS (MARCH 1958)

See the Journal for March 1958, p. 158.

ANNOUNCEMENTS TO MEMBERS

THE HOMES FUND

SUMMARY OF CONTRIBUTIONS RECEIVED TO 25TH MARCH 1958

	No. of Contributors	£	*s.*	*d.*
£1 000 and over	6	6 000	0	0
£100 to <£1 000	30	6 586	3	0
£5 to <£100	853	9 055	1	7
£2 to <£5	2 074	5 682	9	11
Under £2	23 811	12 373	1	0
		£39 696	15	6

THE ANNUAL GENERAL MEETING

Notice is hereby given that the **Annual General Meeting of The Institution of Electrical Engineers** will be held on Thursday, 15th May 1958 at 5.30 p.m., at the Institution Building, Savoy Place, London, W.C.2, to receive and consider the Accounts for the year ended 31st December 1957, and the Annual Report of the Council, and to elect Auditors.

Copies of the Accounts and Report (which will in due course be published in the *Journal*) can be obtained on application to the Secretary about ten days before the date of the meeting.

By order of the Council,
W. K. BRASHER,
Secretary

LECTURE BY MR. DONALD G. FINK

Members are reminded that the Annual General Meeting on the 15th May will be followed at 6.30 p.m. by a lecture on 'Recent Developments in Electronics in the United States', by the President of The Institute of Radio Engineers, Mr. Donald G. Fink.

NOMINATIONS FOR COUNCIL VACANCIES

The following brief biographical details of the Council's nominees for vacancies arising in the Council on the 1st October 1958 are set out for the information of members. A nomination circular is enclosed with this issue of the *Journal* to all Corporate Members and Associates.

PRESIDENT (*one vacancy*)

S. E. GOODALL, M.SC.(ENG.). A.M., 1934; M., 1943. Fellow of Queen Mary College. Chief Engineer, W. T. Henley's Telegraph Works Co. Council [1941–44 (A.M.), 1948–51, Vice-President since 1953]; N.W. Centre Committee (1941–43); N.W. Centre Radio Group Committee (1943–44); Supply Section Committee (1945–50); Chairman of Section (1950–51); service on all principal Committees of Council; Joint Committee on Practical Training in the Electrical Engineering Industry (1946–48); represents Council on a number of outside Committees, including Board of Studies (Engineering) of National Council for Technological Awards; one paper published in *Proceedings* (jointly).

VICE-PRESIDENTS (*two vacancies*)

SIR HAMISH D. MACLAREN, K.B.E., C.B., D.F.C.*, LL.D., B.SC. M., 1945. Director of Electrical Engineering, Admiralty. Council (1950–53, 1954 to date; Vice-President since 1955); service on all the principal Committees of Council; Oversea Activities Committee (1950–55); Joint Committee on Practical Training in Electrical Engineering Industry (1952–56).

A. H. MUMFORD, O.B.E., B.SC.(ENG.). S., 1922; A.M., 1930; M., 1941. Deputy Engineer-in-Chief, The Post Office. Council (1952–55; 1956 to date); Radio and Telecommunication Section Committee (service in various capacities, 1946–48, 1949–51, 1952–55); Chairman of Section (1945–46); service on all principal Committees of Council; Students' Lecturer (1946–48); Radio and Telecommunication Section Premium 1953 (joint award); two papers published in the *Proceedings*.

HONORARY TREASURER (*one vacancy*)

E. LEETE. A., 1917; C., 1929; H.M., 1954. Director, The London Electric Wire Co. and Smiths Ltd., and The Liverpool Electric Cable Co. Council (many years between 1925 and 1949; Honorary Treasurer for 3 full terms of 3 years each); Finance Committee (1929–32; 1940–43; 1946–49); Membership Committee (1927–28; 1929–30; 1931–32); Court of Governors, Benevolent Fund (1934–54; 1956 to date; including 10 years' service as Deputy Chairman); Local Centres Committee (1948–50).

ORDINARY MEMBERS OF COUNCIL

MEMBERS (*four vacancies*)

PROFESSOR M. W. HUMPHREY DAVIES, M.SC. G., 1933; A.M., 1939; M., 1952. Professor of Electrical Engineering, Queen Mary College; Member of Council [1948–51 (A.M.)]; Examinations Committee (1948 to date); Utilization Section Committee (1952–55); Institution representative on City and Guilds Institute Technology Committee; Joint Committee for National Certificates (England and Wales); Engineering Institutions' Examination Part I Committee (1947–57); two papers published in the *Proceedings*; Supply Section Premium 1953 (joint award).

L. DRUCQUER. S., 1920; A.M., 1928; M., 1940. Director and Manager, Home Sales, British Thomson-Houston Co. Formerly Manager, Switchgear Sales, British Thomson-Houston Co (1945–50). Supply Section Committee (1947–50 and 1951–55); Chairman of Section (1955–56); Students' Lecturer (1950–51; 1951–52); one paper published in the *Proceedings* (jointly); extra Premium 1940 (joint award).

J. M. FERGUSON, B.SC.(ENG.), M.I.MECH.E. S., 1936; G., 1938; A.M., 1943; M., 1951. Chief Engineer (Stafford), English Electric Co. Member of Council [1947–50 (A.M.)]; Utilization Section Committee (1955 to date); Education and Training Committee (1947–48); Papers Committee (1947–50); North Staffordshire Sub-Centre Committee (1952–54); Chairman of Sub-Centre (1954–55); one paper published in the *Proceedings* (jointly); Sebastian de Ferranti Premium 1950 (joint award).

H. V. PUGH, M.I.MECH.E. A., 1931; A.M., 1931; M., 1944. Chairman, Eastern Electricity Board. Formerly Controller, London Division, Central Electricity Authority. Supply Section Committee (1950–53); Western Centre Committee (1933–36; 1942–44; 1949–51).

ASSOCIATE MEMBERS (*two vacancies*)

D. C. FLACK, B.SC.(ENG.), PH.D., A.M.I.MECH.E. Age 33. G., 1945; A.M., 1951. Chief Electrical Design Engineer, Bristol Aircraft Ltd. Hon. Secretary of Bristol Students' Section (1947–48); Vice-Chairman (1948–49) and Chairman of Section (1949–50); Western

Centre Committee (1949–50); one paper published in the *Proceedings*; Webber Premium 1957.

D. H. TOMPSETT, B.SC.(ENG.). Age 33. G., 1945; A.M., 1953. Research Engineer, English Electric Co. Formerly General Assistant Technical Engineer, Central Electricity Board. Robert Blair Fellow; Advanced Study in High-Voltage Transmission, U.S.A. (1949–51). North-Western Centre Students' Section Committee (1948); Honorary Treasurer and Assistant Secretary of North Staffordshire Sub-Centre (1956 to date); two papers published in the *Proceedings* (jointly).

COMPANION (*one vacancy*)

SIR JOHN DEAN, B.SC. C., 1937. Chairman and Chief Executive, The Telegraph Construction and Maintenance Co. (1954 to date). Formerly Technical Manager (1945); Executive Director (1946); Managing Director (1950). Also Director of Submarine Cables Ltd. (Deputy Chairman); Selborne Plantation Co. Ltd. (Chairman and Managing Director); Toolpro Ltd. (Chairman); Telcon (Pakistan) Ltd. (Chairman); Telcon Africa (Pty.) Ltd. (Chairman); Telcon Enterprises Overseas Ltd. (Chairman); Telcon Australia Pty. Ltd.; Telecables and Wires Ltd. (Canada).

SYMPOSIUM ON LONG-DISTANCE PROPAGATION ABOVE 30 MC/S

The papers and discussions at the recent Symposium on Long-Distance Propagation above 30 Mc/s will be published at the end of May in a Supplement (No. 8) to Part B of the *Proceedings*. This Supplement—with its contents and index pages, and in a semi-stiff cover—will be complete in a single issue. The prices (post free) are £1 12s. 6d. to members of The Institution and £2 17s. 6d. to non-members.

Order forms have been sent to those who requested them on their registration forms. Any other members requiring copies should apply to the Secretary.

THE INSTITUTION STAFF: EDITORIAL VACANCY

There is a vacancy for an editorial assistant for work on the *Proceedings* of The Institution. The qualifications required are an engineering or a science degree, some engineering experience, and the ability to sub-edit high-class technical copy. A knowledge of foreign languages would be advantageous. Applicants should be between the ages of 25 and 30 (approximately). The salary will depend on age, qualifications and experience. Entry to a superannuation scheme would follow a short period of service.

Those who are interested should write to the Secretary, The Institution of Electrical Engineers, Savoy Place, London, W.C.2, giving full particulars of their education, training and experience.

THE BENEVOLENT FUND

The Court of Governors of the Benevolent Fund wish to express their appreciation to members for responding so generously to the President's appeal circulated with the December 1957 issue of the *Journal*, and to appeals made by some Local Centre Chairmen.

In addition to increased annual subscriptions, nearly 300 members executed deeds of covenant for contributions totalling £435, which with refund of income tax will augment the Fund's annual income by approximately £750.

The Court of Governors are pleased to acknowledge contributions of £6 to the Benevolent Fund, sent by anonymous donors.

BRITISH CONFERENCE ON AUTOMATION AND COMPUTATION

THE BRITISH GROUP FOR THE ENGINEERING APPLICATIONS OF AUTOMATION

On p. 75 of the February issue appeared an announcement about the establishment of Group B—the British Group for Computation and Automatic Control—of the British Conference on Automation and Computation. Recently The Institution of Mechanical Engineers has announced that Group A—the British Group for the Engineering Applications of Automation—was formally constituted on the 20th February 1958. The following societies are associated with the Group:

Institution of Mechanical Engineers
Institution of Civil Engineers
Institution of Electrical Engineers
Institution of Chemical Engineers
Institution of Production Engineers
Incorporated Plant Engineers
Institute of Fuel
Institute of Marine Engineers
Institute of Materials Handling
Institute of Metals
Institute of Welding
Institution of Engineering Inspection
Institution of Gas Engineers
Institution of Mining Engineers
Institution of Municipal Engineers
Institution of the Rubber Industry
Institution of Structural Engineers
Iron and Steel Institute
Plastics Institute
Royal Aeronautical Society
Society of Instrument Technology

The objects of the Group are:

(*a*) To foster the development of the engineering applications of automation.
(*b*) To afford a common meeting ground for the adhering organizations, whereby such of their activities as fall within the purview of the Group can, if so desired, be co-ordinated and extended.
(*c*) To maintain, as may be desirable, liaison with other Groups of the British Conference on Automation and Computation by direct contact and by representation on the General Committee of the British Conference.
(*d*) To encourage and, if desired, to co-ordinate the presentation, at international conferences, of British papers whose subjects fall within the purview of the Group.
(*e*) Through the General Committee of the British Conference on Automation and Computation, to maintain, as may be desirable, liaison with the corresponding national committees of other countries which support such international conferences.

Dr. D. F. Galloway, PH.D., B.SC.(ENG.), WH.SCH., was elected Chairman of the Group, with Mr. J. S. Brough, M.I.MECH.E., M.I.CHEM.E., and Sir Walter Puckey, F.I.I.A., as Vice-Chairmen. Mr. B. G. Robbins, M.SC.(ENG.), F.C.G.I., M.I.MECH.E. (Secretary of The Institution of Mechanical Engineers) was elected Honorary Secretary of the Group, and The Institution of Mechanical Engineers will provide secretarial services for the Group.

At the meeting of the Engineering Applications Group held on the 20th February 1958, it was agreed that a symposium on 'Instrumentation and Computation in Process Development and Plant Design', which is being planned jointly by The Institution of Chemical Engineers, the Society of Instrument Technology and the British Computer Society, should be held under the aegis of the B.C.A.C., subject to the agreement of Group B. Among other points discussed were the possibility of Group participation in the Fourth International Exposition and Congress on Automation in New York during June 1958, relations with the International Federation of Automatic Control and other international organizations of interest, the publication of a Bulletin, and the need for a bibliography.

The constitution of the Engineering Applications Group

(*continued on p. 226*)

LONDON REPORT

DISTRICT MEETING AT OXFORD

The Coming of Fusion

A District Meeting was held at Oxford on the 12th February at 7 p.m. A large audience heard a very interesting paper read by Mr. I. Everson of the A.E.R.E., Harwell, on *The Developing Pattern of Atomic Generation*. The lecture was illustrated by lantern slides.

After a description of the Calder Hall type of reactor, Mr. Everson reached his main theme, namely the possible entry of fusion reactors into future atomic generation—in place of the more advanced types of fission reactor, of which he gave some details. The discussion which followed was very lively and continued in full swing until the meeting was closed at 9.15 p.m.

Mr. H. Shepherd, who represented the A.E.R.E. on the organizing Committee, was in the chair. He is leaving the district, and a motion of thanks and good wishes to him was recorded. Mr. R. Carruthers will now represent Harwell on the Committee. H. S./J. L. T.

DISTRICT MEETING AT READING

Extracting Heat from Cold

On the 20th January 1958, a District Meeting at Reading, under the chairmanship of Mr. H. R. J. Baigent, heard a lecture by Mr. G. Peter Watson on *The Heat Pump with reference to Domestic Installations*. There was a record attendance of 110.

After giving a simple explanation of the principles of the heat pump, Mr. Watson said that, although it was over a hundred years since Lord Kelvin first propounded the idea, development had been retarded by the absence of suitable refrigerants and by the relatively high capital costs involved.

Explaining how a heat pump extracts heat from a low-temperature heat source and increases the temperature of this heat so that it can be usefully employed, he said that most practical heat pumps work on the vapour-compression cycle, and gave details of the four stages, namely evaporation, compression, condensation and expansion. The ratio between the total heat output and the energy taken by the pump determines the usefulness of the machine.

He then went on to describe a refrigerator-heater and to show with the aid of slides how it can be successfully employed in this country for domestic purposes. In most households there is an approximate balance between the demand for heat for hot water and the heat that needs to be extracted from the larder to turn it into a cooled store. This corresponds to approximately 60–100 gallons of hot water per day and a larder with a temperature 15–20° F below the mean house temperature.

A long and lively discussion followed, and many questions were asked by members, and ably answered by Mr. Watson, on the merits and limitations of this machine in its application to domestic premises. The meeting closed after a sincere vote of thanks proposed by Mr. F. A. Ellis, which was carried unanimously. P. J. B.

RADIO AND TELECOMMUNICATION SECTION

The Viewer's View

Events of the last few years, involving international discussion on subjects such as exchange of programmes, standardization of colour systems and the use of u.h.f. bands for television, have focused interest on optimum characteristics for television systems. Mr. L. C. Jesty's paper, *The Relation between Picture Size, Viewing Distance and Picture Quality*, therefore appears at a very opportune time, and his efforts at systematizing viewer reactions are commendable. The paper was read at a meeting of the Radio and Telecommunication Section on the 19th February, and it is reviewed on p. 188.

The experiments on picture quality which Mr. Jesty described could be classified into two groups: (1) those using optically projected pictures, and (2) those using television pictures on 405-line and 625-line standards with facilities for variation of bandwidth. In both of these series of experiments the ratio of viewing distance to picture height as chosen by the viewer was considered to be the criterion of his assessment of picture quality. The consistency between results in the two series of experiments was an interesting feature. The results led the author to conclude that for existing standards using 50 interlaced fields/sec there is a considerable excess of horizontal resolution which is not being generally used by the viewer.

The discussion was opened by Mr. G. G. Gouriet, who was clearly worried by this conclusion, since it meant that for many years we had been transmitting half the spectrum in vain! He felt, though, that there must be some points in the experiments or reasoning which could be challenged. He suggested that to assess picture-quality on the sole basis of viewing distance was perhaps an oversimplification, or that the large size of the room or previous viewing habits prejudiced the observers. Other speakers also showed concern about this last factor, and one showed a slide illustrating that it was possible to get consistent results with a team of viewers in experiments similar to Mr. Jesty's but with the receivers switched off! Many interesting points emerged from further discussion, a notable one being that one could interpret the results as an indication that interlacing was not a satisfactory technique.

The liveliness of the discussion, with not the slightest gap between speakers, was a real tribute to the outstanding way in which Mr. Jesty had introduced his subject, and the Chairman had to stop the meeting before some of those anxious to participate had been able to make their contribution. In his summing up Mr. Jesty was able to deal with only a limited number of points. He did stress that his results showed a continuous reduction in viewing distance as the bandwidth was increased, but beyond his optimum figure there was a much slower return in the corresponding improvement in picture quality. It was therefore misleading to talk of a waste of spectrum.

The publication of this paper with the associated discussion should form an important contribution on an important subject. A. J. B.

MEASUREMENT AND CONTROL SECTION

The Effect of Modern Industrial Requirements on Electrical Instrument Design

To what extent do modern requirements governing the design of electrical instruments differ from what they were fifty years ago? What effects do industrial requirements have on present-day design? These were questions which Dr. G. F. Tagg set out to answer at the meeting on the 21st January, a meeting which had the benefit of an expert's opinion, and which, being held under more informal conditions than usual at Savoy Place, evoked a lively and spontaneous discussion.

The short answer to the first question is that in the early days the number of electrical instruments used was not great, and their forms and functions were decided very largely by the manufacturer. This is no longer so; modern industrial conditions and the very great increase in the use of instruments have meant that the manufacturer has had to take these conditions into consideration and to work in co-operation with the user, particularly when special conditions of use are required.

An important consequence of the use of instruments in numbers, particularly where large arrays are needed, such as on switchboards, control desks and aircraft panels, is the need for making the most effective use of space, and smaller instruments have come much into vogue. Design is also affected by the added complexity of providing control functions to be performed by instruments which are to give indication and often to make records. There is no doubt that materials have a fundamental influence on design, and modern instruments would not have been possible unless parallel developments had been made in materials and components. The speaker dealt also with the particular conditions to be fulfilled in recorders both of the direct-acting and the more elaborate and powerful servo-operated types. A feature which is beginning to be used more in supervisory installations, where conditions of the plant should normally remain constant, is for the instruments to record only departures from the desired values; such a change is then more immediately evident, and masses of unnecessary data are not accumulated.

Attention is being given to the legibility of scales, the appropriate graduation marks to adopt, their spacing and so on. Current work at the British Standards Institution in preparing a code of practice on this aspect of instrument design was mentioned in the discussion. Other subjects discussed were cyclometer-type readings, platform scales, digitizers and methods of recording. It was appreciated that instruments are used in entirely different ways in different applications, and no single system or design can be applicable to all these. There was a plea for omitting the zero adjuster, or at least making it less accessible.

Portable instruments have to stand up to relatively rough handling at times, and one speaker was concerned with the relation between 'bashability' and sensitivity. It is normally not so evident that switchboard-type instruments may also be subjected to rough handling by the manufacturers of switchboards and panels, when these are transported around the factory on trucks. Spring-loaded jewels go some way to mitigate these troubles, and short, taut suspensions, eliminating pivots and jewels entirely, were mentioned. These latter might well have particular application to microammeters required in portable radiation monitors. A. J. M.

CORRESPONDENCE (*continued from p. 187*)

ELECTRICAL SAFETY

From B. B. RAY, M.B.E., M.SC.(ENG.), MEMBER*

The editorial on electrical safety in the December issue of the *Journal* must have aroused great interest throughout the world, for the figures given in it are very interesting. Perhaps some of your readers would be interested in the causes and conditions of electrical accidents in India. In my position as an electrical inspector to the Government of Orissa, India, I have come across a number of accidents, a few details of which I give here.

On high-voltage lines there are normally very few accidents. Most of such accidents may be classed as misadventure; for example, accidents to boys climbing on high-voltage poles. Incidentally I have met two examples of boys climbing on 33kV poles, and being picked up alive. Quite a number of accidents occur on the medium-voltage lines, but most accidents are caused by the 230 volt 50c/s supply. All the fatal accidents have occurred at this voltage, the majority being due to one of the following:

(*a*) Wrong or faulty use of electrical equipment.
(*b*) Disregard of standardized practice.
(*c*) Lack of proper maintenance.
(*d*) Inefficient earthing.

I have also known of several accidents due to kite flying. When a kite comes in contact with the supply it gives a shock to the boy, sometimes resulting in a fatal accident. I believe that the Indian public are not aware of the hazards of electrical accidents, and in some of the coastal areas of India even fatal accidents are not uncommon owing to saline deposition on portable fittings. The Indian Standards Institution has done much work on this problem and there is a move to draw up standards embodying safety rules and safety procedure for all India.

* Mr. Ray is with the Vitro Engineering Corporation—Nangal Fertilizers and Chemicals, Nangal, India. His letter was received on the 14th February 1958.

TALKING BOOKS: AN APPEAL

From D. FINLAY-MAXWELL*

The results of your appeal on our behalf in the December 1957 issue have been very encouraging.

Although a number of volunteers do not mention where they had seen the appeal, no fewer than 163 members have specifically referred to the *Journal* when offering their services.

I think it is a great credit to the character and personality of members of The Institution that so many people are prepared to give up some of their hard-earned leisure time, in the interests of less fortunate members of the community.

Thank you again for your very kind assistance.

* Mr. Finlay-Maxwell is Hon. Organizer of Voluntary Helpers, Nuffield Talking Book Library for the Blind.

NEWS *from the Centres*

EAST MIDLAND CENTRE

Well Toasted

This year's Faraday Lecture on *The Electrification of the British Railways* was received with enthusiasm by two audiences, and all agreed that it was well up to standard. The lecture was prepared by the late Mr. G. H. Fletcher, and delivered by Mr. R. Ledger on the 20th February. In the afternoon some 1400 senior school-children and 200 adults attended, and in the evening there was a further audience of 1700. It was unfortunately necessary to refuse some 500–600 applicants because the capacity of the Albert Hall, Nottingham, was insufficient.

The Centre's Annual Dinner was held on the 28th February at the Victoria Station Hotel, Nottingham, and 162 members and guests attended—a record number.

After a very good meal everyone sat back and enjoyed the speeches, starting with the toast of the City of Nottingham, most ably proposed by the Vice-Chairman, Mr. D. E. Lambert, with an equally good response from the Lord Mayor, Alderman W. Hickling. The toast of The Institution was proposed by Rear-Admiral A. D. Torlesse, Regional Director of Civil Defence, who paid tribute to electrical engineers at sea and in particular on the Monte Bello operation. Dr. Willis Jackson, Vice-President, responded, and held his audience with an account of the uses and development of electrical engineering during the lifetime of The Institution. The Chairman, Mr. J. D. Pierce, proposed the toast of the guests, and the High Sheriff of Nottinghamshire, Lt.-Col. G. H. Vere-Laurie, replied, both speeches ably combining light-hearted banter with the seriousness due to the occasion. Among the guests was Mr. E. G. Phillips, who was celebrating his fiftieth year as a Corporate Member.

The Past-Chairman, Dr. H. L. Haslegrave, proposed an informal toast to the Chairman, who in replying expressed his thanks to those officers of the Centre who had helped to make the evening so successful. Before concluding, the Chairman proposed another informal toast to the toastmaster, Mr. J. P. Tucker, a Past-Chairman, who had so ably carried out these duties for over ten years.

The remainder of the time was spent in a general reunion, which was voted by all to be an outstanding occasion. J. B.

NORTH MIDLAND CENTRE

Tests and Stability

The fifth ordinary meeting of the session was held on the 4th February under the chairmanship of Mr. A. J. Coveney. On this rather special occasion 120 members and visitors were present to hear two papers read, one by Dr. F. H. Last, Mr. E. Mills and Mr. N. D. Norris on *The Organization for Large-Scale Grid System Tests* and the other by Dr. F. Busemann and Mr. W. Casson on *Results of Full-Scale Stability Tests on the British 132 kV Grid System*. These papers were read in advance of their presentation in London, and the interest aroused was demonstrated by the large number attending. The first paper described the preparations necessary before testing could start and illustrated how the operational risks had to be considered against the results to be obtained, bearing in mind the necessity to safeguard the system and the supply. A short film showed the alarming display of control-room instruments during machine pole-slipping, instruments which could be of little value to the operator under such conditions. The second paper described the tests and compared the results with the calculated results obtained from a network analyser and a *microréseau*. The paper was followed by a very interesting discussion, in reply to which Mr. Casson said how useful the points raised would be to the authors. A vote of thanks was proposed by Mr. W. K. Fleming, who felt that the interesting evening pointed to a most successful occasion when the paper was presented in London. He spoke of our pride in the national 132 kV Grid system and the contribution it is making to the country's economy. He felt this was a most important paper, the results of which could considerably improve the testing and performance of the Grid system, and which represented an important contribution to existing knowledge both here and abroad.

Annual Joint Meeting

The annual joint meeting with the Sheffield Sub-Centre was held in Barnsley on the 5th March. There was a total attendance of fifty-four members. The meeting was opened by the Sub-Centre Chairman, Dr. Butler, who welcomed members from the main Centre and from Barnsley, who find it difficult to attend the meetings in Sheffield. The chair was then handed over to Mr. A. J. Coveney, Chairman of the Centre, who assured the meeting that Centre members were always delighted to come to the joint meetings at Barnsley and were very grateful for the invitation and hospitality. In introducing the speaker, Mr. J. D. Humphreys, and his paper, *Earth-Electrode Systems for Large Electric Stations*, the Chairman mentioned that it was always a pleasure to welcome a paper from a Sub-Centre member. After a very interesting paper and prolonged discussion a vote of thanks was proposed by Dr. Butler, who felt that the rapt attention given by the audience was a clear demonstration of their enjoyment. He extended the thanks of the meeting to the Mayor and Corporation of Barnsley for allowing the use of their very fine room, and to Mr. J. H. J. Richards, who made the local arrangements for the meeting. The vote of thanks was seconded by Mr. Coveney, who said that the paper had aroused considerable discussion, which must be very gratifying to the author.

Utilization Group

The Utilization Group met on the 21st January under the chairmanship of Mr. J. L. Browell, fifty-one members being present. Mr. R. H. Dean presented a paper on *Recent Developments in Medium-Voltage High-Breaking-Capacity Fuse Links*, which described new developments to meet the North American market. It was generally considered to be an excellent paper, but one which raised several controversial points. An extensive and critical discussion followed, which was dealt with in a spirited and able manner by the author. A vote of thanks was proposed by the Chairman, who said that he felt the paper was one which was generally required in the industry. The fourth meeting of the Group took place on the 18th February, when Mr. E. Bates read his paper on *Developments of Transportable Thermal-Storage Heaters*. Mr. J. Vaughan Harries, the Utilization Section Chairman, was present at this meeting; he was introduced by our Group

Chairman, Mr. Browell, as an engineer, a Welshman, a poet, a philosopher and an artist, whose Chairman's Address *Joints and Hinges of the World* reflected these attributes. Mr. Vaughan Harries, in reply, indicated his pleasure at being present, and Mr. Coveney, the Centre Chairman, proposed a vote of thanks. Mr. Bates then summarized his paper. This drew a lengthy and spirited discussion, to which Mr. Bates replied in a manner which left no doubt as to his clear grasp of his subject.

Hull District Meetings

The third District Meeting in the Hull area was held on the 16th January, when the Centre Chairman, Mr. A. J. Coveney, gave his address entitled *The Importance of Balance to the Electrical Engineer*. In the address Mr. Coveney discussed very fully the meaning of balance and traced the application of the balance principle from remote periods to the present day. This principle shows itself not only in mechanical devices derived from the early clock mechanisms, in the physical layout of apparatus and equipment and in the highly specialized realm of protection of electrical circuits, but also in those abstract forms relating to management, to the relationships between research, development and production and to judgment generally. The address was illustrated by slides and by a most interesting film showing the testing of circuit-breakers and fuses to destruction. After Mr. Coveney had replied to a number of questions put by members present, a vote of thanks was proposed by Mr. W. S. Milner, convener of the Hull District Meetings, and this was carried with acclamation. Thirty members and friends were present.

The fourth District Meeting in the Hull area was held on the 6th February (instead of on the 3rd April as originally arranged), when Mr. G. Moore gave a lecture entitled *Static Electricity in Industry*. Mr. Moore was then the Chief Electrical Engineer of a local chemical engineering firm dealing with the large-scale production of various kinds of organic liquids, many of which are highly inflammable.

The lecturer described how static charges could accumulate on the surfaces of liquids of high insulating properties when such fluids were transferred along pipes from one container to another. He described in some detail measurements which had been made of the potentials associated with the accrued charges and of the extremely small currents present. He showed that serious danger of explosion could exist with certain highly insulating liquids when pumped from one vessel to another, even when these vessels were earthed, and that to reduce the static charge, an earthed metal grid structure dipping into the liquid was desirable. The vessels should also be filled from the bottom in order to eliminate splashing and spraying which favour the production of static charge. Other effects of static electricity dealt with very ably by the speaker ranged from electrified dusts (particularly liable to explosion) to static charges on vehicles with rubber tyres, particularly road tankers, and the generation of electric charges on belting. After the presentation of the lecture, a vigorous discussion took place, and Mr. J. W. Ledgard, a member from the Grimsby area, then proposed a vote of thanks to Mr. Moore for his interesting and unusual lecture.

Catterick District Meeting

The first District Meeting at Catterick was held on the 7th November 1957, when seventy-eight members, including visitors from the main Centre, heard a lecture by Mr. W. R. Piggott on the *International Geophysical Year and Problems of Ionospheric Propagation*. In opening the meeting the convener, Lt.-Col. R. G. Millar, expressed great pleasure at the way the District Meetings were being supported and said he felt that they were now well established.

The lecture was in three parts: first, a film on ionospheric radar; next a talk, illustrated with slides, on the origin and history of the International Geophysical Year and the part played by Great Britain; and lastly a talk on some ionospheric problems being studied, reference being made to the use of experimental rockets. The discussion was opened by Major D. Coatsworth, who pointed out that an understanding of the ionosphere was essential to the better design and proper use of communication equipment. A vote of thanks was proposed by Brig. D. St. J. Hoysted, who suggested that every effort must be made to make full use of the lessons learnt by this great international experiment. Apart from its obvious value to the communication engineer, other members found the lecture both interesting and topical. The meeting closed on an original note with the relaying through a loudspeaker of signals from the second Russian satellite.

W. J. W.

NORTH STAFFORDSHIRE SUB-CENTRE

At the meeting at Stafford on the 13th January, the Chairman, Mr. H. A. P. Caddell, invited Mr. E. T. Norris to read his paper on *Mechanical Strength of Power Transformers in Service*. In this paper, which dealt with the mechanical performance of transformers under the stresses produced by short-circuits sustained in service, only simple mathematics was employed, and graphs were freely used to present the effects clearly. This approach assisted considerably in clarifying the subject and increasing its interest for the many engineers present who were not directly concerned with transformer design. This led to an active discussion opened by Mr. H. E. Pettitt and joined by ten other members. Mr. E. Jones, in proposing the vote of thanks to the author, said everyone would agree that Mr. Norris's paper and its presentation that evening were most impressive, and his handling of the discussion was masterly. Mr. Norris had said that transformer designers were not ordinary engineers, and since Mr. Jones thought that the materials they used—soft copper and cardboard—would drive any ordinary engineer to drink, he deduced that transformer engineers do not drink. This conclusion did not appear to be so readily accepted as those set out in the paper.

Warm Floors

A District Meeting was held at Burton-on-Trent on the 5th February at which Mr. F. Overstall, presiding over a gathering of about fifty members and friends, introduced Mr. W. M. Stevenson and asked him to read the paper on *Electrical Floor Warming* by Mr. J. W. Moule and himself. The description of this modern method of electric heating, its practical application, and the results already obtained on a great variety of installations in southern Scotland stimulated a discussion in which all opinions were freely ventilated and numerous questions were asked and answered. Mr. H. A. P. Caddell proposed a vote of thanks to the authors for an admirable paper full of facts useful to all interested in developing the use of electricity for heating, and to Mr. Stevenson for the admirable way in which he had presented the paper and dealt with the many questions raised in the

discussion. He stressed the valuable contribution this method would make to the improvement of the national load factor, which has so great an effect on cost of supply. In his reply Mr. Stevenson emphasized the vital necessity of increasing the night load in view of the development of nuclear power stations, which might well proceed more rapidly than was now envisaged.

Towards Cleaner Air

The Faraday Lecture, *Electrification of the British Railways*, prepared by the late Mr. G. H. Fletcher, was presented by Mr. R. Ledger in Stoke-on-Trent on the 18th February, when the Victoria Hall, Hanley, was filled to capacity by an audience numbering nearly 2000. Their close attention and final acclamation showed how very much they enjoyed the lecture with its films and demonstrations. Mr. Ledger was introduced by the Chairman, Mr. H. A. P. Caddell, who also explained the origin and purpose of the Faraday Lectures. In proposing a vote of thanks to the lecturer, Mr. R. W. Palmer said that Mr. Ledger was an expert not only in railway electrification but also in the presentation of his subject in such a charming and fascinating manner. He also thanked the assistants who had so ably demonstrated the equipment. The Lord Mayor of Stoke-on-Trent, Councillor the Reverend Arthur Perry, also complimented Mr. Ledger on his efficient presentation and congratulated him on having in the background an organization capable of bringing such an audience together. He spoke of the need for clean air in our towns and cities and of how railway electrification would contribute to this. He referred to the experiments of Faraday and to those of many other workers, which have led to the great advances made in science and engineering during the last century. Finally he expressed the hope that future Faraday Lectures would be given in Stoke-on-Trent. In his reply Mr. Ledger referred to his grand team of assistants and left it to the audience to imagine the chaos which would result if they let him down one night. He also said that the lecture was a fitting tribute to the life's work of Mr. Fletcher.

Committee Change

The Committee are sorry that Mr. P. D. Gilbey has resigned as Ordinary Member on transferring to another area. Mr. H. Baker, who is already well known in his capacity as Hon. Assistant Secretary (Stone), has been appointed to fill the vacancy until September 1959. L. G.

SOUTHERN CENTRE

Faraday Lecture beats the Clock

The Southern Centre may be counted fortunate in having the Southampton Guildhall available for large gatherings such as the Faraday Lecture. The hall seats 1 720, but never has there been difficulty in finding a Faraday audience to fill it; indeed the difficulty has always been in answering the complaints of the disappointed applicants for tickets.

The lecture was given twice in the same day, in the afternoon to local school-children and in the evening to members of the Centre and members of the public. This year Mr. R. Ledger delivered the lecture prepared by the late Mr. G. H. Fletcher on the subject of *Railway Electrification*.

In the afternoon there were 1 664 children present, including some enthusiastic youngsters from Brighton. Others came from Salisbury, Bournemouth, Winchester, Portsmouth, and 370 from the Isle of Wight, who chartered a steamer to make the journey home. The afternoon audience was really alive to every point made, and their enthusiastic reception of the lecture made it perfectly clear that all the trouble taken to make the arrangements had been well worth while. Mr. Challacombe, Headmaster of Taunton's School, Southampton, proposed the vote of thanks, which was carried with wild acclamation.

At the start of the evening lecture, Dr. Sims, the Chairman of the Centre, introduced the Mayor of Southampton, Councillor R. Dicks, who in turn introduced the lecturer and

By courtesy of the 'Southern Daily Echo'

Mr. R. Ledger, the Faraday Lecturer, with the Mayor of Southampton, on the platform of the Guildhall

Mr. Bell, Manager of the British Railways Carriage Works at Ashford, Kent, who proposed the vote of thanks.

The Faraday Lectures are of interest to a very wide audience, and this one proved no exception. A point noted with interest was the freedom with which the lecturer was able to move about the platform whilst still delivering the lecture, not encumbered by fixed microphones or trailing leads, through the aid of a small v.h.f. personal transmitter. It seems probable that the use of this public-address system will rapidly increase for lecturers who require to be mobile about a platform.

In all some 3 250 persons were privileged to hear this lecture at Southampton. Previous Faraday Lectures at the Guildhall have had to compete at quarter-hour intervals with the chiming of the Guildhall clock, while at the conclusion of each hour there is a protracted carillon performance, which rather tends to dominate the proceedings. On this occasion, however, the Committee had been able to make arrangements for the Faraday lecturer and the spirit of Faraday not to be troubled by competition from the Town Hall clock. E. A. L.

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ANNOUNCEMENTS TO MEMBERS (*cont. from p. 217*)

provides for the election of additional member societies of the type listed above. Applications for membership should be sent to the Honorary Secretary, B.C.A.C., Group A, 1 Birdcage Walk, Westminster, London, S.W.1.

STUDENTS' QUARTERLY JOURNAL

Senior members of The Institution are reminded that they may subscribe for the *Students' Quarterly Journal* which is published in March, June, September and December. The annual subscription is at present 6s., and those wishing to receive the publication are invited to send their remittances to the Secretary, made payable to The Institution of Electrical Engineers. The subscription payable by non-members is 10s. per annum.

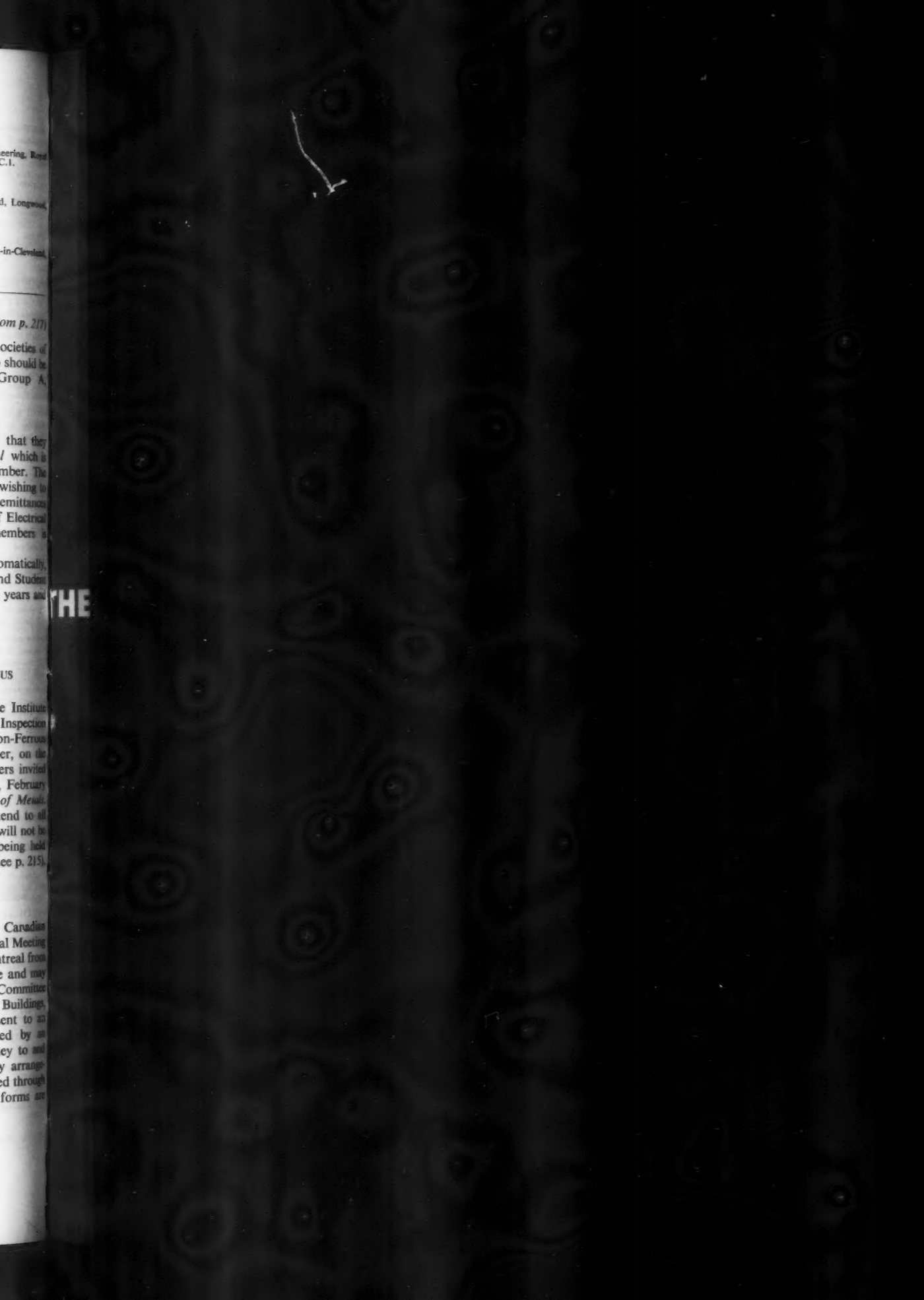
The publication is of course supplied automatically, without charge, to all members of the Graduate and Student Sections and to all Graduates up to the age of 28 years and Students residing oversea.

SYMPOSIUM ON ADVANCES IN INSPECTION TECHNIQUES

CONTROLLING THE PRODUCTION OF NON-FERROUS METALS

The Metallurgical Engineering Committee of The Institute of Metals is holding a symposium on 'Advances in Inspection Techniques as Aids to Process Control in Non-Ferrous Metals Production' at Church House, Westminster, on the 1st May 1958, starting at 9.30 a.m. The ten papers invited for this meeting will be published in the January, February and March issues of the *Journal of The Institute of Metals*. The Committee extends a warm invitation to attend to all members of The Institution; tickets of admission will not be required. The meeting is independent of those being held under the aegis of the B.N.E.C. on the same day (see p. 215).

WORLD POWER CONFERENCE

CANADIAN SECTIONAL MEETING

Copies of the general programme issued by the Canadian National Committee in connection with the Sectional Meeting of the World Power Conference to be held in Montreal from the 7th to 11th September 1958 are now available and may be obtained from the Secretary, British National Committee of the World Power Conference, 201–2 Grand Buildings, Trafalgar Square, London, W.C.2. Each copy sent to an address in the United Kingdom is accompanied by an explanatory circular letter dealing with the journey to and from Canada, the post-conference tours, currency arrangements and so on. All applications must be submitted through the British National Committee; the necessary forms are contained in the general programme.